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**Understanding the impact of classroom noise on children's learning
and well-being, and its modulation by executive functions**

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A thesis submitted for the degree of

Doctor of Philosophy

January 2020

DECLARATION OF ORIGINALITY

I, Jessica Massonnié, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, it has been indicated in the thesis by citing the authors.

JOURNAL ARTICLES

This thesis includes research that appears in the following papers:

Chapter 2: Massonnié, J., Rogers, C., Mareschal, D. & Kirkham, N. (2019). Is Classroom Noise Always Bad for Children? The Contribution of Age and Selective Attention to Creative Performance in Noise. *Frontiers in Psychology* 10: 381.
<https://doi.org/10.3389/fpsyg.2019.00381>

Chapter 5: Massonnié, J., Frassetto, P., Mareschal, D. & Kirkham, N. (under review). Learning in noisy classrooms: Children's reports of annoyance and distraction from noise are associated with individual differences in mind-wandering and switching skills.

Chapters 6 and 7: Massonnié, J., Frassetto, P., Mareschal, D. & Kirkham, N. (under review). Scientific collaboration with educators: Practical insights from an in-class noise reduction intervention.

Flanker task used in Chapters 2, 3, 5 and 7: Anwyl-Irvine, A., Massonnié, J., Flitton, A., Kirkham, N., & Evershed, J. (2019). Gorillas in our Midst: an online behavioural experiment builder. *Behavior Research Methods*, <https://doi.org/10.3758/s13428-019-01237-x>

During my PhD, I have also contributed to the following paper: Hobbiss, M., Massonnié, J., Tokuhamma-Espinosa, T., Gittner, A., Arson de Sousa Lemos, M., Tovazzi, A., ... Gous, I. (2019). 'UNIFIED': Bridging the Researcher-Practitioner Divide in Mind, Brain and Education. *Mind, Brain and Education*, 13(4), <https://doi.org/10.1111/mbe.12223>

ABSTRACT

Noise is a prevalent part of primary school. Yet, it is unclear why some pupils are more affected by it than others. Theoretical and empirical evidence suggest that noise impacts learning by deviating attention. This hypothesis has been tested on adult populations using working memory and attention tasks, but not on children. This thesis presents laboratory and school studies filling this gap.

Chapter 2 investigates the impact of moderate verbal noise (single-talker noise) and multi-talker classroom noise on reading comprehension, text recall and mathematics performance, among a sample of children in Years 4 to 6. Noise had a detrimental effect on text recall and mathematics, but only when the noisy session was presented before the silent session. There was no difference between the impact of the two types of noise. Inhibitory control was not identified as a protective factor. Better working memory was protective when doing mathematics in noise – but this was not found for reading comprehension and text recall.

In Chapter 3, children in Years 1 to 6 were engaged in two idea generation tasks, with or without the presence of moderate multi-talker noise. Noise only had a detrimental impact on the original of ideas for children in Years 1 to 3, and this was evident in only one of the two tasks. Better inhibitory control was protective when generating new ideas in noise, especially for children in Years 1 to 3.

Studies from Chapters 2 and 3 provide new insights into the mechanisms underlying the impact of noise. They also reveal a challenge for researchers and educators; namely, that the

objective impact of noise on performance does not align with children's self-reported experience of being distracted.

Chapter 4 explores different dimensions of children's reactions to noise, in a sample of pupils in Years 5 and 6. Here, perceiving noise as interfering with an ongoing activity in the classroom was partly dissociable from feeling annoyed by it. Children who reported greater difficulties in switching from one task to another also reported greater noise interference and annoyance. Children who reported greater mind-wandering reported greater interference, but not annoyance. Chapter 5, based on the same sample, highlighted that behavioural tests of sustained attention and working memory were associated with noise interference, but not annoyance. Together, these results bridge the gap between self-report, and behavioural assessments of distractibility.

Finally, Chapters 6 and 7 reported on two separate mindfulness and sound awareness interventions that were co-designed with teachers, and implemented among the same sample as in Chapters 4 and 5. The reduction in noise levels was more important in the sound awareness and in the control groups than in the mindfulness group. Only the sound awareness group was associated with reduced feelings of noise interference and annoyance. Improvements in reading comprehension were more important in the mindfulness group than in the sound awareness group.

In conclusion, this thesis shows that the impact of noise on learning and well-being is partly underlined by attentional mechanisms, and suggests practical solutions to reduce children's negative reactions to noise.

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The world used to be silent
Now it has too many voices
And the noises are constant distraction
They multiply, intensify
They will divert your attention to what's convenient
And forget to tell you about yourself
We live in an age of many stimulations
If you are focused, you are harder to reach
If you are distracted, you are available

“Shut up” - Savages

Chapter 1 - General Introduction

1.1. Chapter overview

The principal aim of this chapter is to review the available evidence about the impact of noise on primary school children's learning and wellbeing.

First, the notions of sound and noise will be defined and operationalised to allow for a comprehensive understanding of the current literature on noise. The different types and levels of noise that are present in school settings will be introduced.

Second, the impact of noise on learning outcomes will be discussed by including two lines of evidence. The first line of evidence focuses on teacher-pupil communication, that can be affected by the presence of noise. The second line of evidence focuses on children's task performance, when they are engaged in solo work. Three different cognitive mechanisms that are suggested to underlie the impact of noise on task performance will be introduced. These mechanisms have not been empirically tested on children populations yet. Such investigations would allow for a better understanding of the interindividual differences in the impact of noise within primary school populations. Filling this gap in the research is therefore identified as one of the key aims of this thesis.

The third part of this chapter will move beyond the objective impact of noise on learning outcome to review children's subjective reactions to noise (e.g. feelings of distraction and annoyance). Again, there is very little work investigating the source of interindividual differences in children's reactions to noise. Most of the available literature is on adult

populations. Filling this gap in the research is therefore identified as the second key aim of this thesis.

The main aims and an outline of the thesis will be summarised in the fourth part of this chapter. The use of mixed methods will be emphasised, to compare laboratory-based research with in-class, naturalistic research.

1.2. Noise in schools

1.2.1. Definitions of sound and noise

Classrooms are full of life and full of sounds. Teachers and students are engaged in on-topic and off-topic discussions, people move around, chairs scrape the floor. Internal devices, such as ventilation systems or printers, and sounds from outdoor (e.g. transportation noise) also contribute to the ambient auditory landscape (Bruxelles Environnement, 2015).

Not all of these sounds are wanted or pleasant, nor are they relevant for a given learning situation. This is where they would be characterised as noise. Noise can be conceived of as an unwanted (Erickson & Newman, 2017), unpleasant (Kanakri, Shepley, Varni, & Tassinari, 2017), distractive (Kanakri et al., 2017), and/or nonmeaningful (Gang & Teft, 1975) sound. Every noise is a sound, but every sound is not a noise. Characterising a sound as noise involves a negative judgment, “[it] is subjective, and dependent on the internal state of the individual. Different individuals may exhibit unique responses to the same auditory stimuli” (Kanakri et al., 2017, p.2). This subjectivity can be perceived as a threat to scientific investigation.

However, by taking into account the goal of a person, and the relevance of the sound with regard to this goal, it is possible to externally operationalise what constitutes a noise. Indeed, annoyance from sounds arises “in a situation in which the sound and the person’s intended activities are incompatible” (Boman & Enmarker, 2004, p. 208). In the classroom, educational goals involve listening to the teacher and engaging in solo or group work. Sounds that are incompatible with these activities (because they refer to off-topic content, distract pupils from their learning activity, or make it difficult to hear the teacher) can be defined as noise.

Two main factors interact to predict the impact of noise on learning and well-being: the type of noise (e.g. speech noise, speech noise mixed with traffic noise), and its intensity. The intensity of sounds is measured in decibels (dB) and is recorded with sound level meters. Indicative values for the sound intensity of different activities and situations are presented in Figure 1.1 (Bruxelles Environnement, 2015; Daniel, 2007; Erickson & Newman, 2017). Sounds above 70-80dB are especially tiring, painful, or irritating. On average, children in primary schools are exposed to 72dB of noise (Shield & Dockrell, 2004).

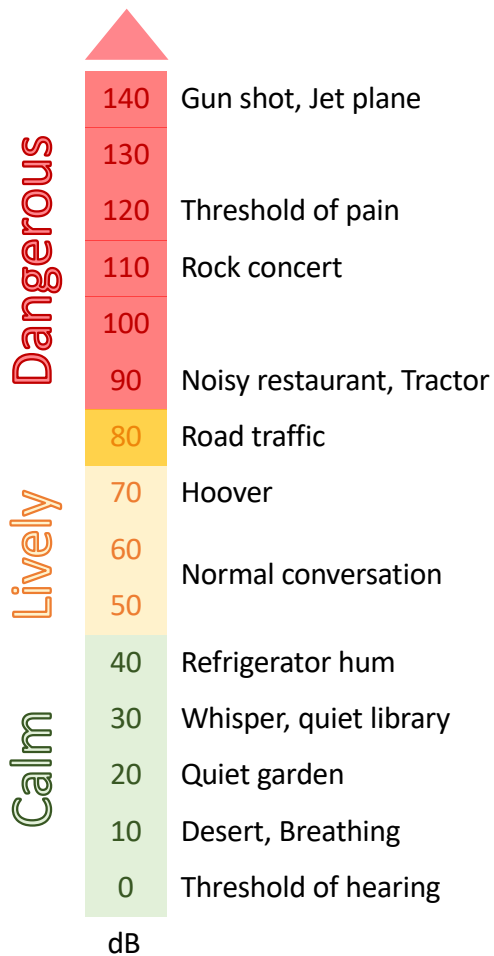


Figure 1.1. Average estimates of sound intensity for common activities

When comparing the sound intensity of different stimuli, it should be kept in mind that the decibel scale is not linear, but logarithmic. A doubling in sound intensity does not correspond to a doubling in decibels, but to an increase of 3dB: two tractors put side by side, each generating 90dB, would give an overall value of 93dB, not 180dB (Nathanson & Berg, 2019). Furthermore, the sound intensity recorded by sound level meters does not exactly corresponds to the subjective loudness of sounds. For a sound to be perceived as twice as loud, it is estimated that it should increase by 6-10dB (Nathanson & Berg, 2019).

Finally, once a sound is generated in the classroom, it can decay pretty quickly, or persist over time, depending on acoustic factors, such as either the presence of absorbent material (e.g. carpets), or bouncing surfaces (flat, bare walls). The reverberation time of a sound indicates the time required (in seconds) for the level of a sound to decay by 60 dB after it has been turned off (Acoustical Society of America, 2010).

1.2.2. Noise levels in schools

The amount of noise children can be exposed to in their classrooms is decided by legislations. In the United Kingdom and in the United States, an upper limit of $L_{Aeq,30min}$ 35dB¹, and a reverberation time below .60 are recommended for unoccupied teaching spaces (Acoustical Society of America, 2010; Education Funding Agency, 2015). These recommendations include the amount of external noise getting into teaching spaces (e.g. road traffic noise, railway noise, aircraft noise), as well as noise coming from fixed building features (e.g. ventilation systems, drainage).

In a survey on 16 primary schools in London, Shield & Dockrell (2004) reported an average level of 47dB in unoccupied classrooms, which is 12dB above the official recommendations. Noise levels between 55 and 60dB were recorded *outside* of the school. Values can go beyond 60dB for schools situated near airports (Clark, Head, & Stansfeld, 2013; Hygge, Evans, & Bullinger, 2002). These measures do not take into account the noise generated by pupils inside the building.

¹ L_{Aeq} is a measure of equivalent continuous sound pressure level during a specific time interval, and A-weighted, to take into account the varying sensitivity of the ear to sound for different frequencies (World Health Organization, 2018).

In schools which are exposed to moderate amounts of external noise (55-60dB), other pupils' activities appear to be the most disturbing source of noise for teachers and pupils, covering noise coming from outdoor, or from internal devices (Enmarker & Boman, 2004; Shield & Dockrell, 2004). Sound levels range from 56.3dB for silent reading/testing, to 76.8dB for group work involving movement. In between, individual work can be estimated to generate 64.7dB, and group work 72.9dB (Shield & Dockrell, 2004). But is classroom noise always bad for learning?

1.3. The impact of classroom noise on learning outcomes

Classroom noise can impact on children's learning outcomes by: 1) impairing teacher-pupil communication, 2) interfering with children's task performance (Klatte, Bergström, & Lachmann, 2013; Shield & Dockrell, 2003). Each of these is discussed in turn below.

1.3.1. The impact of noise on teacher-pupil communication

Classroom noise can result in a cumulative loss of educational information when it interferes with teacher-pupil communication. This is the case when irrelevant sounds (e.g. background babble) partly mask the message conveyed by the teacher, thereby reducing speech intelligibility. The comparison between the level of a desired signal (e.g. the voice of the teacher) and the level of irrelevant background noise can be expressed by a signal-to-noise ratio. A signal-to-noise ratio of 15dB is generally recommended in classrooms (Picard & Bradley, 2001; Shield, Greenland, & Dockrell, 2010). If children are engaged in individual work while occasionally chatting, they generate around 64.7dB. It means that the teacher would have to raise their voice to 80dB to be heard clearly (Erickson & Newman, 2017). Since a

typical conversation is at 60dB, this is exhausting for teachers, who have a higher prevalence of voice problems (Martins, Pereira, Hidalgo, & Tavares, 2014). Children might also not properly understand what is being said, and might therefore not respond appropriately.

Indeed, the capacity to process speech in noise, or to reconstruct degraded phonological information develops until adulthood (Elliott, 1979; Hazan & Barrett, 2000; Klatte et al., 2013; Klatte, Lachmann, & Meis, 2010). Difficulties are especially important for children in their early primary school years (Jamieson, Kranjc, Yu, & Hodgetts, 2004), whose classes are the noisiest (Picard & Bradley, 2001). Even if children manage to understand speech within background noise, this is causing an extra burden on their capacity to process, store and act according to the perceived information (Klatte, Meis, Sukowski, & Schick, 2007). Ultimately, these auditory difficulties would result in a loss of learning opportunities.

As such, optimal classroom acoustics (reverberation time below .60; Klatte, Hellbrück, Seidel, & Leistner, 2010), and a reduction in noise levels (Maxwell & Evans, 2000) might help children to attend to, perceive and generate linguistic inputs. Berg, Blair and Benson (1996) recommend keeping noise levels in occupied classrooms below 50dB. This would favour children's language development and have a cumulative effect on educational information that is transmitted through oral language. Optimal listening conditions would ultimately benefit children's performance.

1.3.2. The impact of noise on task performance

Studies assessing the impact of noise on task performance have focussed on written, visual tasks, contrary to the auditory tasks prevalent in the speech perception literature. Two strands of research can be distinguished: 1) community studies focusing on long-term exposure to noise, comparing children living in more or less noisy areas; 2) experimental studies focusing on short-term exposure, displaying various noise stimuli while children are engaged in specific tasks.

1.3.2.1. Community studies

Community studies are mainly about transportation noise: aircraft noise, road traffic noise, and railway noise. They reveal mixed findings, depending on the type of noise, and task children are engaged in.

The most robust findings associate chronic exposure to aircraft noise to impairments in pupils' reading skills (Clark & Sörqvist, 2012; Evans, Hygge, & Bullinger, 1995; Evans & Maxwell, 1997; Haines, Stansfeld, Head, & Job, 2002), an effect that can be explained by cumulative difficulties in speech perception (Evans & Maxwell, 1997; however, see Van Kempen et al., 2010). Chronic exposure to aircraft noise has also been associated with lower scores on nationally standardised tests (Clark & Sörqvist, 2012), lower mathematics performance (Haines et al., 2002), and a reduced ability to complete meaningful sentences (Matheson et al., 2010; Stansfeld et al., 2005). This can potentially be related to children's difficulty to switch their attention from the aircraft noise back to the task at hand (Van Kempen et al., 2010). However, aside from these negative findings, several studies showed no significant

impact on spelling, writing, scientific reasoning (Haines et al., 2002), motor tasks (Van Kempen et al., 2010), and sustained attention (Matheson et al., 2010; Stansfeld et al., 2005; Van Kempen et al., 2010). Although long-term memory (e.g. memory from a text read the day before) is likely to be impaired (Evans et al., 1995) by chronic exposure to aircraft noise, many other memory systems (e.g. short-term memory, working memory, prospective memory) are not impaired (Matheson et al., 2010; Stansfeld et al., 2005; Van Kempen et al., 2010).

While aircraft noise can be concentrated in specific areas, road traffic noise is likely to be more widespread. Contradictory results have been reported. Matheson et al. (2010) and Stansfeld et al. (2005) found a *positive* and linear impact of road traffic noise on the recall and recognition of stories. Instead of measuring noise as a continuous variable, Lercher, Evans, and Meis (2003) compared two groups of children, exposed to less than 50dB, or more than 60dB of environmental noise, consisting mainly in road traffic and railway noise. The children who had less exposure performed better on recall and recognition tasks, and on incidental memory (incidental memory reflects a bi-product of engaging in a task, children being unaware of having learned something at the time of learning). These results seem to contradict those of Matheson et al. (2010) and Stansfeld et al. (2005). It is possible that the positive relationship between road traffic exposure and memory occurs for values under 50dB (Matheson et al., 2010), and therefore does not appear when comparing children exposed to less than 50dB, with children exposed to more than 60dB of environmental noise (Lercher et al., 2003). No significant impact of road traffic noise on the ability to complete sentences, on working memory, prospective memory (Matheson et al., 2010; Stansfeld et al., 2005), and sustained attention (Matheson et al., 2010; Sanz, García, & García, 1993; Stansfeld et al., 2005) have been reported.

The most convincing pieces of evidence about the effects of transportation noise come from studies tracking the evolution of children's performance before and after changes in their auditory environment. Hygge et al. (2002) followed two cohorts of children: one cohort was living near an airport in Munich that was about to close, the other was living in the area where the new airport would be constructed. Each cohort was compared to a control group of similar socio-economic status, but less exposed to the aircraft noise. Before its closure, children living near the old airport had lower performances than their control group on measures of word and paragraph reading, long-term memory, short-term memory and reaction time. Two years after the old airport closed, these differences were not significant anymore. In contrast, subjects living near the new airport had lower performances in word and paragraph reading, long-term memory, and reaction time compared to their control group. These differences did not exist before the new airport was open. This research is closer to showing a *causal* effect of aircraft noise than the other cross-sectional studies and suggests that the negative effect of noise on cognitive abilities can be reversible. Cross sectional data on noise abatement programs have also shown positive effects on mathematics (Cohen, Krantz, Evans, Stokols, & Kelly, 1981 - for aircraft noise) and reading skills (Bronzaft, 1981 - for railway noise).

Overall, chronic exposure to transportation noise has been quite strongly associated with reading difficulties. Evidence about negative effects on attention and memory is, in contrast, rather weak. Evans and Lepore (1993) provide an important review of older studies using slightly different methodologies that arrives at essentially the same conclusions. One limitation about community studies is that they are mostly based on noise measurements

taken outside of school premises. It is therefore difficult to understand how external noise interacts with internal noise to predict learning outcomes.

Shield and Dockrell (2008) measured both external and internal noise levels in London primary schools. External levels were taken from 142 schools, which were part of three boroughs. Systematic negative associations between noise levels, 7-year-olds and 11-year-olds' academic performance in English, Maths and Science were found in only one out of three boroughs assessed. Most of the effects disappeared when socio-economic status was controlled for. Only when the schools exposed to more than 60dB were selected did the association hold. Internal noise levels were measured on a subsample of 16 schools. Again, the associations between background noise in occupied classrooms and school performance did not hold after controlling for socio-economic status.

Internal noise combines external transportation noise with sounds coming from in-class conversations, movement, and building devices. To better understand the respective impact of each type of noise on children's performance, it is necessary to move to laboratory studies, which offer more control over the stimuli children are exposed to.

1.3.2.2. Experimental studies

Experimental studies assess the impact of short-term (also called "acute") noise exposure on children's performance. Here, the available evidence reported in Table 1.1 was reviewed based on four main factors that vary between studies (see Figure 1.2): 1) the noise stimuli (type and volume) participants were exposed to, 2) their age, 3) the task they were assessed

on, 4) the testing environment (e.g. school settings, or laboratory). Some exclusion criteria were applied. Studies using music, white noise, pink noise, or isolated tones were not included, because they are not usually part of the classroom environment. Only results about typically developing pupils in preschool, primary school, and middle school were included. Even if this thesis ultimately focuses on primary school pupils (e.g. 5- to 11-year-olds in the UK), being more inclusive in the review of the literature helps to shed light on developmental effects. The evidence on adult populations will be addressed in part 1.3.3. 'Mechanisms underlying the effect of noise on task performance'.

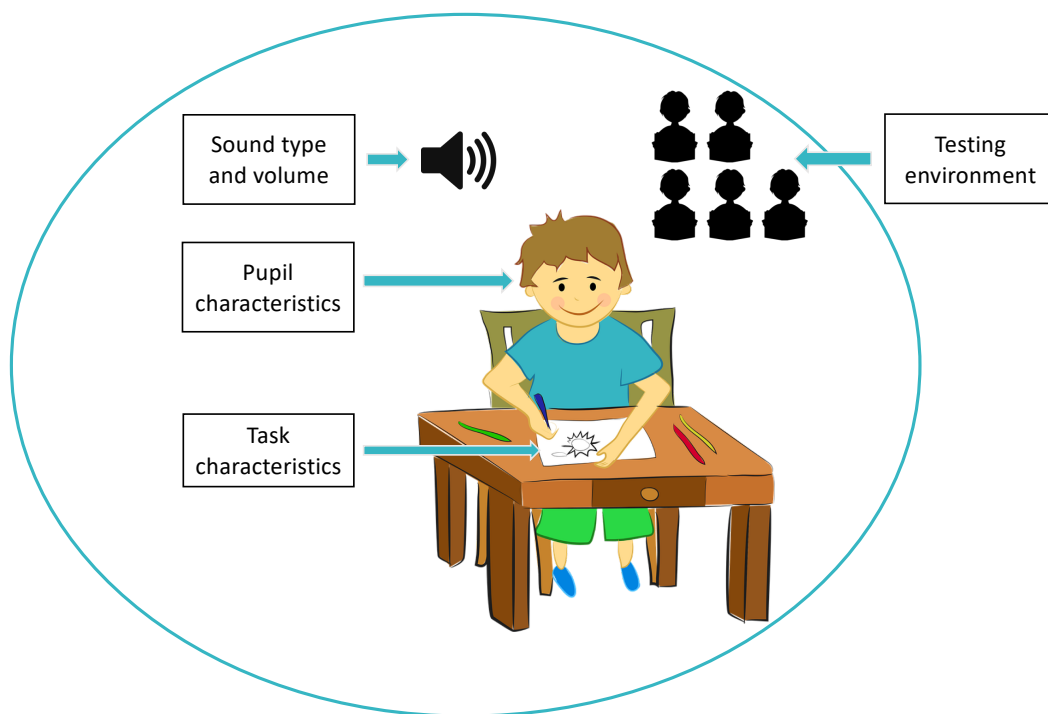


Figure 1.2. The impact of noise on learning outcomes depends on the specific sound, task, and environment children are tested in

Overall, moderate (50-66dB) verbal (speech) noise has a negative effect on performance, compared to quiet conditions (around 40dB). This has been shown using tasks of serial recall (Elliott, 2002; Elliott & Briganti, 2012; Klatte, Lachmann, Schlittmeier, & Hellbrück, 2010; Klatte et al., 2007), text recall and recognition (Boman, 2004), word comprehension (Boman, 2004), reading skills, spelling and speed of processing (Dockrell & Shield, 2006). The evidence on mathematics is contradictory: Dockrell and Shield (2006) found a negative impact, but Kassinove (1972) – who used noise stimuli that were louder than other studies (70-80dB) did not. It should be noted that Boman (2004) reported no significant effects of speech noise on other variables, such as the recall of sentences, face and name recognition, word fluency, and sustained attention.

Mixed findings have been found for transportation noise. Boman (2004) did not report any significant effect of road traffic noise on various memory systems, word fluency, word comprehension or sustained attention. In contrast, Hygge (2003) reported a negative impact of transportation noise on text recall and recognition. Although various types of stimuli were used (aircraft noise, road traffic noise, train noise, and any pairwise combination), the effects were mainly seen on stimuli including aircraft noise. Train noise on its own did not have a deleterious effect, fitting with Klatte et al. (2007)'s findings on serial recall. Finally, Ljung, Sörqvist and Hygge (2009) reported a negative impact of road traffic noise on reading speed and mathematics involving arithmetic and geometry, but not on reading comprehension and verbal mathematics reasoning. All these studies about acute exposure to transportation noise used stimuli of moderate intensity (66dB).

Table 1. Review of the experimental studies investigating the impact of noise on children's performance

Authors	Sample	Noise Type (Level)	Testing room	Learning outcome	→ Main results
Boman (2004)	• 13- to 14-year-olds (n = 96) Between	• Quiet (38dB)	Laboratory	• Text recall	• Quiet > Speech
		• Speech (66dB)		• Text recognition	• Quiet > Speech
		• Road traffic (66dB)		• Free recall of sentences	• No effect of noise
				• Cued recall of sentences	• No effect of noise
				• Face and name recognition	• No effect of noise
				• Word fluency	• No effect of noise
				• Word comprehension	• Quiet > Speech
				• Attention (Letter Cancellation Task)	• No effect of noise
Connolly, Dockrell	• 11- to 13-year-olds	• Mixed noise (50dB)	External room	• Reading comprehension (literal)	→ 14- to 16-year-olds: 50dB>70dB
	(n = 361) Within	• Mixed noise (70dB)	in school	• Reading comprehension (inferential)	→ No effect of noise
	• 14- to 16-year-olds			• Word learning from a text	→ No effect of noise
	(n = 308) Within			• Reading time	→ No effect of noise
Mydlarz & Cox (2019)	• 11- to 13-year-olds	• Mixed noise (50dB)	External room	• Reading comprehension (literal)	→ 11- to 13-year-olds: 64dB>50dB
	(n = 203) Within	• Mixed noise (64dB)	in school	• Reading comprehension (inferential)	→ No effect of noise
	• 14- to 16-year-olds			• Word learning from a text	→ 11- to 13-year-olds: 64dB>50dB
	(n = 104) Within				14- to 16-year-olds: 50dB>64dB

				• Reading time	→ 11- to 13-year-olds: 50dB>64dB 14- to 16-year-olds: 64dB>50dB
Dockrell & Shield (2006)	• 8 year-olds (n = 158) Between	• Quiet (no measure) • Speech (65dB) • Mixed noise (65dB)	Not specified	• Reading skills • Spelling (Auditory stimuli) • Speed of processing • Maths (arithmetics)	→ Mixed noise > Quiet > Speech → Mixed noise > Quiet > Speech → Quiet > Speech; Mixed noise → Quiet > Speech
Elliott (2002)	• 8 year-olds • 9 year-olds • 11 year-olds (n = 131)	• Quiet (45dB) • List of words (72dB) • Repetition of one word (72dB)	Laboratory (sound- attenuated)	• Serial recall of digits	→ 8 year-olds and 9 year-olds: Quiet > List words > Word repeat. 11 year-olds: Quiet > List words; Word repeat.
Elliott & Briganti (2012)	• 7- to 9-year-olds (n = 34)	• Quiet (no measure) • High-frequency words (70dB) • Low-frequency words (70dB)	Laboratory	• Serial recall of words (Difficulty adapted to each participant)	→ Quiet > High-frequency words; Low-frequency words.
Hygge (2003)	• 12- to 14-year-olds (n = 1358) Mixed- design (All in quiet + One type of sound).	• Aircraft (66dB) • Road traffic (66dB) • Train (66dB) • Multi-talker foreign speech(66dB) • Aircraft (55dB)	Usual classroom	• Text recall	→ Quiet > Aircraft (66dB) Quiet > Road traffic (66dB) Quiet > Aircraft (55dB) Quiet > Train + Aircraft (66dB) Quiet > Aircraft + Road (66dB)

		<ul style="list-style-type: none"> • Road traffic (55dB) • Aircraft + Train (66dB) • Train + Aircraft (66dB) • Aircraft + Road traffic (66dB) • Road traffic + Train (66dB) 		<ul style="list-style-type: none"> • Text recognition 	<p>→ Quiet > Aircraft (55dB)</p> <p>Quiet > Aircraft + Train (66dB)</p>
Kassinove (1972)	<ul style="list-style-type: none"> • 8- to 9-year-olds (n = 40) Between • 11- to 12-year-olds (n = 40) Between 	<ul style="list-style-type: none"> • Quiet (no measure) • Storytelling (70-80dB) 	<p>External room in school</p>	<ul style="list-style-type: none"> • “Easy” Maths (arithmetics) • “Complex” Maths (arithmetics) 	<p>→ No effect of noise</p> <p>→ No effect of noise</p>
	<ul style="list-style-type: none"> • 6- to 7-year-olds (n = 53) Mixed-design 	<ul style="list-style-type: none"> • Quiet • Foreign Speech (54dB) 	Laboratory	<ul style="list-style-type: none"> • Serial recall of nouns presented pictorially 	<p>→ Quiet > Irrelevant speech</p> <p>Quiet > Mixed noise</p>
Klatte, Lachmann, Schlittmeier & Hellbrück (2010)	<p>(All in quiet + One type of sound.</p> <ul style="list-style-type: none"> • 7- to 9-year-olds (n = 21) Within 	<ul style="list-style-type: none"> • Mixed noise without speech (54dB) • Quiet • Foreign Speech (54dB) • Mixed noise without speech (54dB) 	Laboratory	<ul style="list-style-type: none"> • Serial recall of nouns presented pictorially (Difficulty adapted to each participant) 	<p>→ Quiet; Mixed noise > Speech</p>

Klatte, Meis, Sukowski & Schick (2007)	• 7- to 8-year-old (n = 21)	• Quiet (36dB) • Foreign Speech (57dB) • Train sound (62dB)		• Serial recall of digits	→ Quiet; Train > Speech
Ljung, Sörqvist & Hygge (2009)	12- to 13-year-olds (n = 187) Between	• Quiet (no measure) • Road traffic (66dB) • Multi-talker speech (66dB)	Usual classroom	• Reading speed • Reading • Maths (arithmetic, geometry) • Maths reasoning	→ Speech; Silence > Traffic → No effect of noise → Quiet > Traffic → No effect of noise
Slater (1968)	12- to 13-year-olds (n = 263) Between	• Quiet (45-55dB) • Mixed noise (55-70dB) • Mixed noise (75-90dB)	Usual classroom	• Reading speed • Reading accuracy	→ No effect of noise → No effect of noise
Zentall & Shaw (1980)	7- to 8-year-olds (n = 24) Within	• Mixed noise (69dB) • Mixed noise (64db)	External room in school	• Maths (arithmetics)	→ Mixed noise 69dB > 64dB
	7- to 8-year-olds (n = 20) Within	• Mixed noise (70dB) • Mixed noise (57dB)	External room in school	• Attention (Letter Cancellation Task)	→ Mixed noise 57dB > 70dB

Multiple experiments within the same study are represented with dotted lines. “Mixed noise” (unless otherwise specified) refers to stimuli mixing noise from movements, objects being used, voices and/or transportation noise.

Of special interest here are studies using a combination of noise sources: verbal noise, noise coming from movement, and/or transportation noise. We refer to these combinations as “mixed noise”. Compared to a quiet condition, moderate (55-65dB) mixed noise has a negative effect on speed of processing (Dockrell & Shield, 2006) and on serial recall (but only when the task difficulty is not adapted to each participant's abilities; Klatte, Lachmann, Schlittmeier, et al., 2010). However, and contrary to what has been found with single-talker verbal noise, mixed noise (Dockrell & Shield, 2006; Slater, 1968) as well as multi-talker noise (Ljung et al., 2009), do not have a negative impact on mathematics or reading tasks. Children exposed to moderate mixed noise actually perform better than their peers placed in a quiet condition, when tested with reading and spelling tasks (Dockrell & Shield, 2006).

Furthermore, studies comparing different levels of mixed noise (without a quiet control condition) revealed different effects depending on the task at hand and on children's age. High levels (70dB) of mixed noise are detrimental to children's performance when they are engaged in a sustained attention task (in comparison to a condition of 57dB), but seem preferable to mathematics performance, when compared to a condition of 69dB (Zentall & Shaw, 1980). Connolly et al. (2019) exposed 11- to 13-year-olds, and 14- to 16-year-olds to 50dB, and 70dB of mixed noise. They measured the pupils' reading speed, literal and inferential comprehension, and their capacity to learn words from a text. There were no significant differences between the two levels of noise, except for the 11- to 13-year-olds who had higher scores of literal reading comprehension in the low-noise condition (50dB). Complex interactions emerged, however, when comparing noise levels of 50dB and 64dB. Children between 11 and 13 years of age read faster, had a better literal understanding of the text, and demonstrated better word learning when exposed to 64dB as compared to 50dB. In

contrast, children between 14 and 16 years of age had better word learning and read faster when exposed to 50dB, compared to 64dB of noise.

How can we explain the differential impact of verbal noise and mixed noise on task performance? And why would mixed noise have positive effects on performance?

1.3.3. Mechanisms underlying the effect of noise on task performance

Three main processes have been proposed to account for the impact of noise on performance (for a summary, see Clark & Sörqvist, 2012; Hughes, Vachon, & Jones, 2007; Klatte et al., 2013): 1) Order processing, 2) Phonological/Semantic processing, and 3) Attention capture. Each of these is presented in more detail below.

1.3.3.1. The order processing account

The order processing account states that when the background noise is composed of a series of distinct, successive sounds, it is perceived as ordered, and therefore it interferes with the processing of order in participants' task. To give an example, remembering a list of digits involves recalling each separate digit in a specific order. Hearing, at the same time, a list of irrelevant digits, or letters, would tap into similar resources and reduce performance. Such an impairment has been shown in adults (Jones & Macken, 1993; Jones, Macken, & Murray, 1993) and children (Elliott, 2002; Elliott & Briganti, 2012; Klatte, Lachmann, Schlittmeier, et al., 2010; Klatte et al., 2007), using various types of items to remember (e.g. lists of digits or consonants), and various types of distracting sounds (e.g. series of digits, words, syllables,

vowels, tones). The repetition of a single auditory stimulus can also cause disruption, if it contains *changing-state* characteristics (e.g. a varying pitch, or regular interruptions by periods of silence; Jones et al., 1993). What is important here is for the sound to be *segmented*. According to this account, this process of seriation is more important than the nature of the signal itself (whether it contains speech or not; Jones et al., 1993; Jones & Tremblay, 2000).

Studies supporting the order processing account have mostly been done in laboratory environments where participants are engaged in serial recall tasks. In these studies, the noise stimuli are usually prepared so that each irrelevant sound is presented at the same time as the item to remember. It is, therefore, hard to generalise these results to more naturalistic noise stimuli (e.g. hearing full utterances or conversations), or to more naturalistic tasks, in which order processing is less obvious (e.g. text recall, reading comprehension; Boman, 2004; Dockrell & Shield, 2006). Even if full sentences can ultimately be broken down into individual signals, text recall and reading comprehension involve the construction of complex mental models that goes beyond the memory of individual, successive words (Gernsbacher, Varner, & Faust, 1990; Kintsch, 1998). Furthermore, it is hard to understand whether mixed noise without speech, which is a continuous, irregular superposition of noise stimuli, would qualify as a *changing-state* stimuli, explaining its negative impact on children's serial recall (Klatte, Lachmann, Schlittmeier, et al., 2010). Ultimately, the order processing account does not offer an explanation for the *positive* impact of mixed noise on reading and mathematics (Connolly et al., 2019; Dockrell & Shield, 2006; Zentall & Shaw, 1980).

1.3.3.2. The phonological and semantic processing accounts

The order processing account is often tested in comparison with alternative theories putting forward the role of speech-like features to explain the impact of irrelevant sounds on task performance. According to this account, phonological information and/or semantic information present in both the sound and the task at hand would interfere with each other and result in an impediment in performance. Baddeley (2000; 2003) suggests that working memory (a limited capacity system allowing for the maintenance and storage of information) is composed of three sub-systems: a central executive, a visuo-spatial sketchpad, and a phonological loop. The phonological loop allows for the storage and subvocal rehearsal of phonological representations. Crucially, it processes both visual items (e.g. a list of visually presented words), which are recoded verbally, and auditory items (e.g. irrelevant sounds presented simultaneously). Both streams of information would gain access to the phonological store, auditory stimuli interfering with the rehearsal of the items to remember. Since Baddeley's model emphasises the role of phonological information, meaningful words, or non-meaningful words (non-words, or words in a foreign language), can all be assumed to impact serial recall through the same process (Salamé & Baddeley, 1982). However, Baddeley's theory is not entirely incompatible with other accounts highlighting the role of semantic processing (Neely & LeCompte, 1999). Baddeley (2000) proposed a "strategy switch hypothesis" according to which semantic encoding is used when phonological coding is not sufficient (either because the information to be remembered is especially complex, or because it has to be recalled in the long-term). Overall, theories highlighting the role of phonological and semantic processes suggest that irrelevant sounds must have speech-like characteristics to interfere with performance.

This idea accounts for a wider range of effects than the order processing theory, when considering the impact of classroom noise on task performance. Speech interference can explain the detrimental impact of verbal noise on reading performance (Dockrell & Shield, 2006), mathematics (Dockrell & Shield, 2006), and memory of verbal information (Boman, 2004; Klatte, Lachmann, Schlittmeier, et al., 2010), provided that all tasks involve the manipulation of phonological and/or semantic information. It can explain why mixed noise does not have a negative impact on reading (Slater, 1968) and mathematics (Dockrell & Shield, 2006), since the overlap of multiple conversations with additional environmental noise can partly mask the phonological and semantic information contained in the speech signal. Similarly, multi-talker speech (Ljung et al., 2009) and foreign speech (Hygge, 2003) have less salient semantic information, which can explain why they do not affect reading (Ljung et al., 2009), mathematics (Ljung et al., 2009) and text recall (Hygge, 2003) – but see Klatte, Lachmann, Schlittmeier, et al. (2010); Klatte et al. (2007). However, it is hard to understand why mixed noise without speech can have a detrimental impact on children's text recall (Klatte, Lachmann, Schlittmeier, et al., 2010), nor why mixed noise would have a positive impact on reading (Dockrell & Shield, 2006), reading comprehension (Connolly et al., 2019), spelling (Dockrell & Shield, 2006) and mathematics (Zentall & Shaw, 1980).

1.3.3.3. The attention capture account

A third, and perhaps more promising, theoretical account posits that noise captures participants' attention and, in doing so, distracts them from their main task (Hughes et al., 2007). According to Klatte et al. (2013), "auditory events that are salient (e.g., of personal significance, such as one's own name), unexpected (e.g., slamming of a door), or deviant from

the recent auditory context (e.g., change in voice in a speech stream) have a strong potential to capture attention.” (p.3). This definition is quite broad and it is hard to exactly operationalise which features in the noise are capturing attention, since semantical and physical parameters (e.g. fluctuations in the noise signal) are both considered. What is crucial for Hughes et al. (2007) is for the noise to be unpredictable. This is likely to be the case for verbal noise which is not composed of regular sounds (such as the repetition of the same words), and for mixed noise composed of various, irregular auditory events (e.g. noise coming from conversations, distant road traffic).

Empirical studies on adult populations did test whether task performance under noisy conditions was mediated by attentional processes. Some clarification is needed regarding the terminology that was used, because attentional processes were actually measured using working memory tasks. In the noise literature, working memory is considered a gateway, filtering out irrelevant information to prevent interference with the ongoing task (Beaman, 2004; Conway, Cowan, & Bunting, 2001; Sörqvist, Ljungberg, & Ljung, 2010). However, in the executive function literature, pervasive in educational research, the capacity to select what to attend to and to resist interference from irrelevant distractors is referred to as inhibitory control, or executive attention (Diamond, 2013). Working memory mostly refers to the storage and manipulation of currently relevant information that is no longer perceptually present (Diamond, 2013). The differentiation between working memory and inhibitory control over development continues to be debated (Brydges, Fox, Reid, & Anderson, 2014; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003). Both skills are executive functions that ultimately allow us “to concentrate and pay attention, when going on automatic or relying on instinct or intuition would be ill-advised, insufficient, or impossible” (Diamond, 2013, p. 135).

However, the two constructs are theoretically, and empirically distinguished. Key definitions from the noise literature, and from the executive function literature are provided in Table 1.2.

Table 1.2. Conceptualisation of working memory and inhibitory control in the executive function and noise literature

	Executive function literature	Noise literature
Working memory	“Working memory [...] involves holding information in mind and mentally working with it (or said differently, working with information no longer perceptually present” (Diamond, 2013, p. 141)	“It is clear that the ability to handle cognitive interference is a dimension on which high- and low-working memory span individuals differ.”(Conway et al., 2001, p. 334)
Inhibitory control	“Inhibitory control of attention (interference control at the level of perception) enables us to selectively attend, focusing on what we choose and suppressing attention to other stimuli. We need such selective attention at a cocktail party when we want to screen out all but one voice.” (Diamond, 2013, p. 136)	“The relationship between working memory capacity [...] and the effects of speech on reading comprehension was mediated by immediate intrusion errors. It should be noted that we do not argue that the immediate suppression mechanism is separate from working memory capacity as usually measured with other tasks. The mechanism is rather a part of that construct and responsible for the ability to avoid interference from unattended speech.” (Sörqvist, Halin, et al., 2010, p. 75)

In the noise literature, working memory appears to be protective against the effects of verbal noise on serial recall (Sörqvist, 2010b), text recall (Sörqvist, Ljungberg, et al., 2010), and reading comprehension (Sörqvist, Halin, et al., 2010). In other words, participants with better working memory are less impaired by noise. A closer look at the measures suggests that this protective effect actually reflects a process of inhibitory control. Sörqvist, Halin, et al. (2010)'s and Sörqvist, Ljungberg, et al. (2010)'s working memory test involved having participants identify and remember the three smallest numbers in a list. It was the ability to suppress irrelevant numbers immediately from memory that mediated the impact of noise on performance. A sustained attention task which does not require the inhibition of irrelevant representations did not mediate the impact of verbal noise on text recall (Hygge, Boman, & Enmarker, 2003).

Crucially, the protective effect of inhibitory control occurs for specific types of sounds that produce a *deviation effect*. A deviation effect occurs when a sound clearly stands out from the auditory context (for example, in the series “c c k c c c”; Sörqvist, 2010b), and cannot be predicted (as is the case when hearing a new story; Sörqvist, Halin, et al., 2010). Sounds that are regularly changing (having *changing-state* characteristics) impact serial recall irrespective of participants' working memory (Elliott & Briganti, 2012). The attention capture and order processing accounts have been combined in the so-called *duplex-mechanisms* accounts of auditory distraction (Hughes et al., 2007; Sörqvist, 2010b). However, since most school tasks do not involve a strict processing of order, we believe that combining the attention capture account with the phonological / semantic account is more promising in the school context.

The attention capture account can explain why verbal and mixed noise both have a negative impact on memory since they redirect children's attention away from the information to remember (e.g. in serial recall tasks, this can lead to "miss out" some of the items that are presented; Elliott, 2002; Elliott & Briganti, 2012; Hygge et al., 2003; Klatte, Lachmann, Schlittmeier, et al., 2010; Klatte et al., 2007). However, since verbal noise also contains salient semantic and phonological information, it can be more detrimental to performance than mixed noise, when participants are engaged in verbal tasks (Boman, 2004; Dockrell & Shield, 2006; Slater, 1968).

One key advantage of the attention capture account, compared to both the order processing and phonological / semantic accounts, is that it can explain the *positive* impact of mixed noise on reading and mathematics performance. To explain this further, connections have to be made with the creativity literature. Creativity involves the construction of new ideas and products, which are considered both unique and useful (Runco, 2003). Using several canonical creative cognition tasks, in which participants had to generate multiple ideas and/or find links between words, Mehta, Zhu, and Cheema (2012) discovered that adults gave more original answers when exposed to 70dB of mixed noise, as compared to low noise (50dB) and high noise (80dB). Participants did feel distracted and less able to concentrate when exposed to moderate levels of noise, in comparison to lower levels of noise. According to the authors, this disruption led to more abstract processing, enhancing conceptual associations and creative thinking. Disruption under high noise levels (80dB) would not be beneficial because participants spend less time on the task (maybe to reduce their exposure to noise).

It is unclear how these results would transfer to school tasks such as reading comprehension and mathematics, but one clue might lie in the view that learning and creativity are intertwined processes (Guilford, 1967). For example, idea generation could help children to imagine what might follow a particular event in a story, or to make inferences. Similarly, in mathematics, idea generation could be used to redefine problems, or to find multiple ways to solve them (Beghetto & Kaufman, 2014; Pang, 2015). In line with this idea, Zentall and Shaw (1980) found that 7- to 8-year-olds exposed to 70dB of mixed classroom noise had better mathematics performance than those exposed to 64dB of noise. They also found that 70dB of noise reduced children's performance at an attention task, when compared to 57dB, which fits with Mehta et al. (2012)'s idea that moderate mixed noise captures attention. Similarly, in Dockrell and Shield (2006), 8 year-olds exposed to 65dB of mixed noise performed worst at a speed of processing task (which required sustained attention), but better at reading and spelling tasks than children placed in a quiet condition. Moderate mixed noise could therefore disrupt performance at low-level processing tasks, but provide the optimal amount of distraction for more abstract tasks.

1.3.4. Inter-individual differences in the impact of classroom noise on learning: future avenues for research

It should be kept in mind that all the existing studies directly measuring the role of attention and/or working memory when working in noise have been carried out on adults. Evidence on children is more indirect, relying on the assumption that, if attention plays a role in the ability to cope with noise, younger children, who have lower attentional skills, will be more impaired by noise than older children and adults when engaged in memory tasks. Two existing studies

have adopted this approach to study the impact of noise on serial recall across development (Elliott, 2002; Klatte, Lachmann, Schlittmeier, et al., 2010) but have yielded contradictory results.

No study with children has incorporated direct measures of attentional processes to test whether attentional processes modulate the impact of noise on task performance, as was done with adults (Sörqvist, 2010b; Sörqvist, Halin, et al., 2010; Sörqvist, Ljungberg, et al., 2010). Clearly distinguishing working memory from inhibitory control is critical in order to better understand the processes at play (Diamond, 2013). Even if both skills have been associated with school performance (Cragg & Gilmore, 2014; Diamond, 2013, 2014; Mareschal, 2016), it is possible that inhibitory control is the main protective factor when working in noise. Identifying why some children have more difficulties to work with background noise and which skills are protective of noise would help to understand inter-individual differences in the classroom. It would also be a first step towards designing suitable interventions to help children cope with noise.

When helping children to cope with noise, one might wonder whether it would be simpler to directly ask them how distracting and disturbing they find classroom noise. Children reporting greater degrees of annoyance could be placed in the quieter corner of the classroom when they are engaged in homework, or provided with noise cancelling headphones. This is unlikely to be a straightforward issue. Experimental studies have shown very little relation between children's perception of the effects of noise upon their performance, or their annoyance reactions, and the actual effect of noise on their performance (Hygge, 2003; Slater, 1968). To better understand this issue, it helps to go back to the operational definition of noise as a

source of interference and consider it in the context of the theoretical and empirical models of *subjective* reactions to noise. Both sides of the question are important, if one wants to foster both learning and well-being in the classroom.

1.4. Subjective reactions to noise

1.4.1. Noise interference, noise annoyance, and noise sensitivity

As stated above, characterising a sound as a noise involves a negative appraisal: noise is an unwanted (Erickson & Newman, 2017), unpleasant (Kanakri et al., 2017), distractive (Kanakri et al., 2017), and/or nonmeaningful (Gang & Teft, 1975) sound. In the literature on the impact of noise on learning outcomes reviewed in part 1.2, noise was operationalised as a sound that was incompatible with the participants' task, resulting in a drop of performance. This implies a process of interference sometimes referred to as disturbance (Stallen, 1999), or distraction (Boman & Enmarker, 2004; Kjellberg, Landström, Tesarz, Söderberg, & Åkerlund, 1996). The order processing, phonological/semantic and attention capture accounts all proposed cognitive mechanisms explaining such interference. However, most studies did not ask participants about their subjective reactions to noise (e.g. whether they actually found it disturbing). Some limited evidence suggests that both children's (Hygge, 2003; Slater, 1968) and adults' subjective reactions to noise (Mehta et al., 2012) do not co-vary with the actual impact of noise on performance. This is even the core proposal of Mehta et al. (2012) that

feeling distracted can actually be associated with better creativity in the presence of moderate mixed noise².

How then did these studies assess participants' reactions to noise? Hygge's (2003) questions related to the perceived difficulty of the texts to be recalled, to the amount of effort that was devoted to reading and learning from the text, and to feelings of disturbance and irritation. Slater's (1968) questions were not described in detail, but referred to children's perceptions of the effect of noise upon their performance and to feelings of annoyance. Finally, Mehta et al. (2012) used a composite measure, asking participants how distracting they found the room ambience while completing the study, how well they could concentrate, and how comfortable they found the room. None of these studies compared participants' subjective reactions to behavioural tests of attentional skills. This is especially important given that Mehta et al. (2012) used their subjective measures to suggest that the impact of noise was mediated by attentional processes. This idea is congruent with mediation analyses carried out with behavioural measures of attention (Sörqvist, 2010b; Sörqvist, Halin, et al., 2010; Sörqvist, Ljungberg, et al., 2010) but self-report and behavioural measures would both benefit from being compared directly, along with the impact of noise on performance. Such a triangulation process is illustrated in Figure 1.3.

² The existence of discrepancies between adults' subjective reactions to noise and the actual effects of noise on performance suggests that it is not only a matter of children being too young to be aware of their cognitive processes.

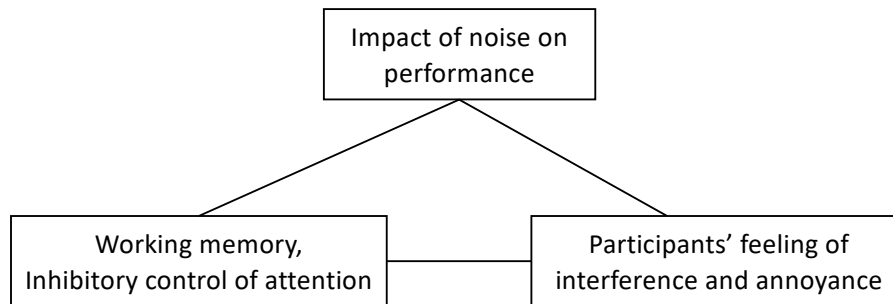


Figure 1.3. Triangulating the impact of noise on performance with participants' subjective reactions to noise and with behavioural measures of working memory and inhibitory control

Crucially, it is possible that attentional difficulties only relate to *some* but not all reactions to noise. Kjellberg et al. (1996) and Stallen (1999) points out the importance of dissociating the concepts of noise interference and annoyance. As explained before, noise interference, or the difficulty of achieving goals when noise taxes resources that are less available for the main task, has more to do with cognitive (and potentially attentional) mechanisms. It does not contain an emotional reaction in itself. Noise annoyance, however, involves a negative emotional reaction that might, or might not arise following interference from noise, depending on participants' judgements and attitudes (Guski, 1999; Stallen, 1999). For example, perceiving other people's conversations as a social signal instead of an intrusion into privacy can be related to less annoyance towards that source of noise. The tendency to be afraid of aircrafts and to judge them as unsafe can be associated with more annoyance towards aircraft noise. Metacognitive strategies, such as the capacity to regulate noise interference once it has been noticed, by exercising cognitive control, or disappearing into daydreams, might also play a role in determining the level of annoyance experienced (Boman & Enmarker, 2004).

It is difficult to understand the specific cognitive and social mechanisms behind participants' reports of noise annoyance and interference because most experimental and survey studies investigating inter-individual differences have confounded the two constructs, or have merged them under the broader term of "noise sensitivity". Noise sensitivity reflects "the internal states (be they physiological, psychological, or related to life style or activities conducted) of any individual which increase their degree of reactivity to noise in general" (Job, 1999). It is measured with a single question, respondents placing themselves on a continuum from "not sensitive at all", to "very sensitive", or with multiple items evaluating their reactions to noise in various situations – for a review, see Zimmer and Ellermeier (1999). A commonly used questionnaire is that of Weinstein (1978), and it mixes items related to cognitive processes of interference (e.g. "I'm good at concentrating no matter what is going on around me"), with other items related to emotional reactions and annoyance (e.g. "Sometimes noises get on my nerves and get me irritated"; "I get annoyed when my neighbours are noisy"). The noise sensitivity literature has investigated physiological and personality factors associated with more or less reactivity to noise.

1.4.2. Inter-individual differences in noise sensitivity: personality factors

Two main personality variables have been associated with noise sensitivity: neuroticism and extraversion (Belojevic, Jakovljevic, & Slepcevic, 2003). On the one hand, neuroticism is related with a higher sensitivity to noise (Belojevic & Jakovljevic, 2001; Dornic & Ekehammar, 1990; Stansfeld, Clark, Jenkins, & Tarnopolsky, 1985). Neuroticism is the tendency to be emotionally instable, to feel tensed, nervous, worried, or anxious. These results are therefore in line with studies showing a positive correlation between noise sensitivity and measures of

depression, stress and anxiety (Ekehammar & Dornic, 1990; Park et al., 2017; Stansfeld, Clark, Jenkins, et al., 1985; Zimmer & Ellermeier, 1999). On the other hand, extraverts tend to be less sensitive to noise (Dornic & Ekehammar, 1990; Weinstein, 1978).

Differences between neurotics and extraverts have been explained in terms of coping strategies, and/or arousal levels (Belojevic et al., 2003). Neurotics would have lower arousal thresholds, and, as such, would be more easily stressed and overwhelmed by noise, with anxiety or worries making it difficult to reframe the perception of noise as positive. Extraverts would, on the contrary, seek more external stimulations and arousal. They would perceive noise as a social signal, and would have a lower need for privacy, which would lead to more positive and less stressful attitudes toward noise (Dornic & Ekehammar, 1990; Weinstein, 1978). All the findings reported here are based on self-report measures, which makes it hard to identify the physiological and cognitive mechanisms at play. Comparisons with behavioural studies are therefore useful.

1.4.3. Inter-individual differences in noise sensitivity: physiological factors

Early studies from the 1980' onwards investigated whether noise sensitivity and noise annoyance were related to basic physiological or sensory processes such as heart rate, skin conductance, or auditory processing. Results relating blood pressure, skin conductance and uncomfortable loudness levels to noise sensitivity are inconsistent (Gang & Teft, 1975; Öhrström, Björkman, & Rylander, 1988; Stansfeld et al., 1985; Stansfeld, 1992; Thomas & Jones, 1982), possibly because of contextual factors. Individuals who are very annoyed by, or sensitive to, noise showed an acceleration of heart rate when exposed to noise in laboratory

conditions (Gang & Teft, 1975; Stansfeld, 1992) but an opposite pattern was found when subjects were tested in their natural environment (Stansfeld et al., 1985). Moreover, adults with high and low sensitivity to noise do not differ in terms of absolute auditory thresholds or capacity to discriminate between tones of different intensities (Ellermeier, Eigenstetter, & Zimmer, 2001; Stansfeld et al., 1985; Stansfeld, 1992). Psychoacoustical factors account for around 15% of the interindividual variance in noise sensitivity when measured in a continuous way (Ellermeier et al., 2001). This leaves room for other explanatory factors.

More recent studies using brain imaging methods have shifted the focus of investigation from the peripheral auditory system to central processes (for an overview, see Heinonen-Guzejev et al., 2017, 2018). Noise sensitive individuals seem to have difficulties encoding auditory information and discriminating changes in sound noisiness³ (Kliuchko, Heinonen-Guzejev, Vuust, Tervaniemi, & Brattico, 2016). It has been suggested that they have reduced sensory gating; that is to say, that they have difficulties inhibiting or filtering unnecessary sensory inputs (Shepherd, Hautus, Lee, & Mulgrew, 2016).

1.4.4. Inter-individual differences in reactions to noise: future avenues for research

To our knowledge, all the studies investigating inter-individual differences in noise sensitivity have been carried out on adults. Studies putting forward the role of personality variables are important to understand inter-individual differences and to highlight the role of attitudes and emotional coping when confronted with noise. However, since personality is by definition a stable trait that is constant over time and over situations, focusing on this dimension alone

³ Here, noisiness does not refer to the sound intensity, but to changes in the waveform.

would not help to understand potential variations in children's reactions to noise when they are confronted to different types of noise. It would also not leave room for interventions.

Physiological and brain studies have suggested a role for attentional processes, but these have not been measured by behavioural tests. For example, heart rate variations have been interpreted in light of attentional mechanisms (Gang & Teft, 1975; Stansfeld et al., 1985) – a deceleration reflecting withdrawal and acceleration attention. Stansfeld (1992) suggested that, in most cases, noise sensitive individuals are more likely to *attend* to sounds. Shepherd et al. (2016) proposed that sensory gating could be regulated by top down attentional processes, but they did not include a measure of executive attention in their study.

Here, distinguishing multiple facets of noise sensitivity, such as interference, and annoyance, might be especially useful. Indeed, it is possible that attentional mechanisms are mostly involved when perceiving interference, but not annoyance from noise, as this last dimension includes further feelings and emotional reactions.

1.5. Main goals and outline of the thesis

The main goal of this thesis is to better understand inter-individual differences in: 1) the impact of noise on school performance, 2) children's subjective reactions to noise. The focus will be on the role of executive functions, especially working memory and the inhibitory control of attention. This will fill a gap in the existing literature by extending the evidence that is available based on adult populations to child populations. In addition, the current thesis will connect these questions to the growing and promising literature surrounding the role of

executive functions in school achievement. School-based interventions aiming to influence the generation and perception of classroom noise will be investigated in light of the cognitive mechanisms suggested to underlie the impact of noise on task performance and well-being. The thesis will unfold as described below.

Chapter 2 will test the impact of verbal and mixed noise, both presented at moderate levels, on children's text recall, reading comprehension, and mathematics. Each type of noise will be compared to the other, and to a silent condition. Interactions between the impact of noise and children's working memory and inhibitory control will be investigated.

Chapter 3 will connect with the creativity literature, comparing children's performance on two idea generation tasks, with or without the presence of moderate background noise. Again, interactions with working memory and inhibitory control will be tested. Both Chapters 2 and 3 will inquire about children's feeling of distraction when working under noise.

Chapter 4 will investigate children's reactions to noise more broadly by focussing on children's performance within the school context. This chapter will investigate multiple facets of noise sensitivity, and will test whether noticing noise in the classroom, perceiving noise as interfering with an on-going task, and being annoyed by noise can be distinguished as separate dimensions in children.

Chapter 5 will connect survey and behavioural methodologies for assessing the impact of noise on children. It will test whether and how each type of reaction to noise (noticing the

noise, feeling interference and annoyance) relates to behavioural measures of attentional skills and working memory.

Chapters 6 will present the design and implementation of two types of interventions which have the potential to modify the generation and perception of noise in the classroom; namely, mindfulness and sound awareness interventions. Children's self-reported feelings and changes in mood and attention during the interventions will be reported.

Chapter 7 will report on a pre and post-test study designed to test whether the interventions described in Chapter 6 are associated with a change of classroom noise levels, children's reactions to noise, executive functions, and/or school performance.

Most of the studies from this thesis involve children in their late primary school years (between 8 and 11 years of age). This age range was selected so that participants have sufficient reading and writing skills to fill-in a survey and report on their subjective reactions to noise. Chapter 3 extends this age range to include children from 5 to 11 years of age. This offers a wider developmental window through which the role of attentional skills when performing an idea generation task in noisy conditions can be investigated.

As shown by the chapter outlines, this thesis combines different methods that can be classified according to two main dimensions represented in Figure 1.4. The first dimension discriminates 1st person (self-report) measures from 3rd person (behavioural) measures. First person measures are mostly used to investigate participants' subjective reactions to noise, while 3rd person measures assess the impact of noise on task performance. The second

dimension discriminates studies carried out in laboratory settings from studies carried out *in vivo* (e.g. in classrooms). Each chapter will be introduced along with a diagram visually representing where it falls along these two dimensions. In line with the main goals of translational, Mind, Brain and Education research, the use of mixed-methods allows to better connect, and reflect on the links between behavioural, laboratory-based research, and naturalistic research taking place in a classroom environment (Brookman-Byrne & Thomas, 2018).

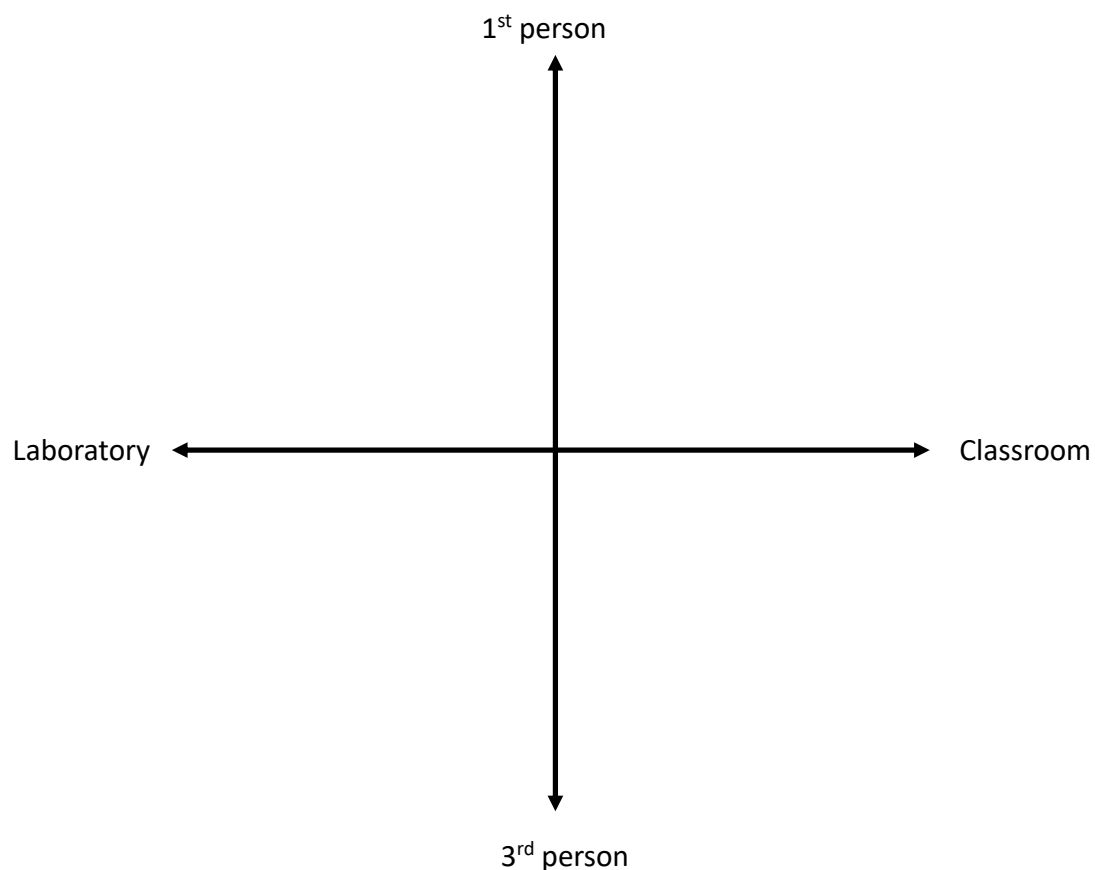


Figure 1.4. The methodological approaches of this thesis can be classified according to two dimensions, representing (1) the use of 1st person or 3rd person measures, collected in (2) laboratory or classroom settings

Chapter 2 - Comparing the impact of verbal and mixed classroom noise on academic performance, and its modulation by executive functions

2.1. Chapter overview

As highlighted in Chapter 1, children are exposed to a variety of types and levels of noise in the classroom. Although some schools are particularly exposed to transportation noise, with potential chronic effects on children's cognition (Evans & Lepore, 1993), in less sensitive areas, noise mainly comes from the pupils themselves (Shield & Dockrell, 2004). When engaged in school tasks, children are exposed to verbal noise, such as hearing their neighbour talking. Often, this verbal noise is embedded within multiple conversations, or with noise coming from movement, chairs scraping, or distant road traffic. This latter multi-layered noise is referred to as mixed noise.

The comparison between verbal noise and mixed noise has empirical and theoretical relevance. It raises questions about which specific components within the noise (e.g. semantic information) explain its effects on cognition. However, there is a lack of studies using both types of noise and assessing their impact on several school tasks. The current chapter aims at filling this gap in the literature by assessing the impact of verbal noise and mixed noise on children's performance in text recall, reading comprehension and mathematics. Furthermore, it remains unclear why some children are more affected by noise than others. Drawing on promising findings with adult participants (Sörqvist, Halin, et al., 2010; Sörqvist, Ljungberg, et al., 2010), this chapter investigates whether the impact of noise interacts with children's inhibitory control and working memory.

The approach used in this Chapter is shown in Figure 2.1. Experiment 1 used a laboratory-based methodology. Recorded samples of verbal and mixed noise were created. School performance, working memory and inhibitory control were all measured through behavioural tasks (3rd person approach). Moreover, children's subjective reactions to noise were briefly investigated by asking them how distracting they found the noise (1st person approach).

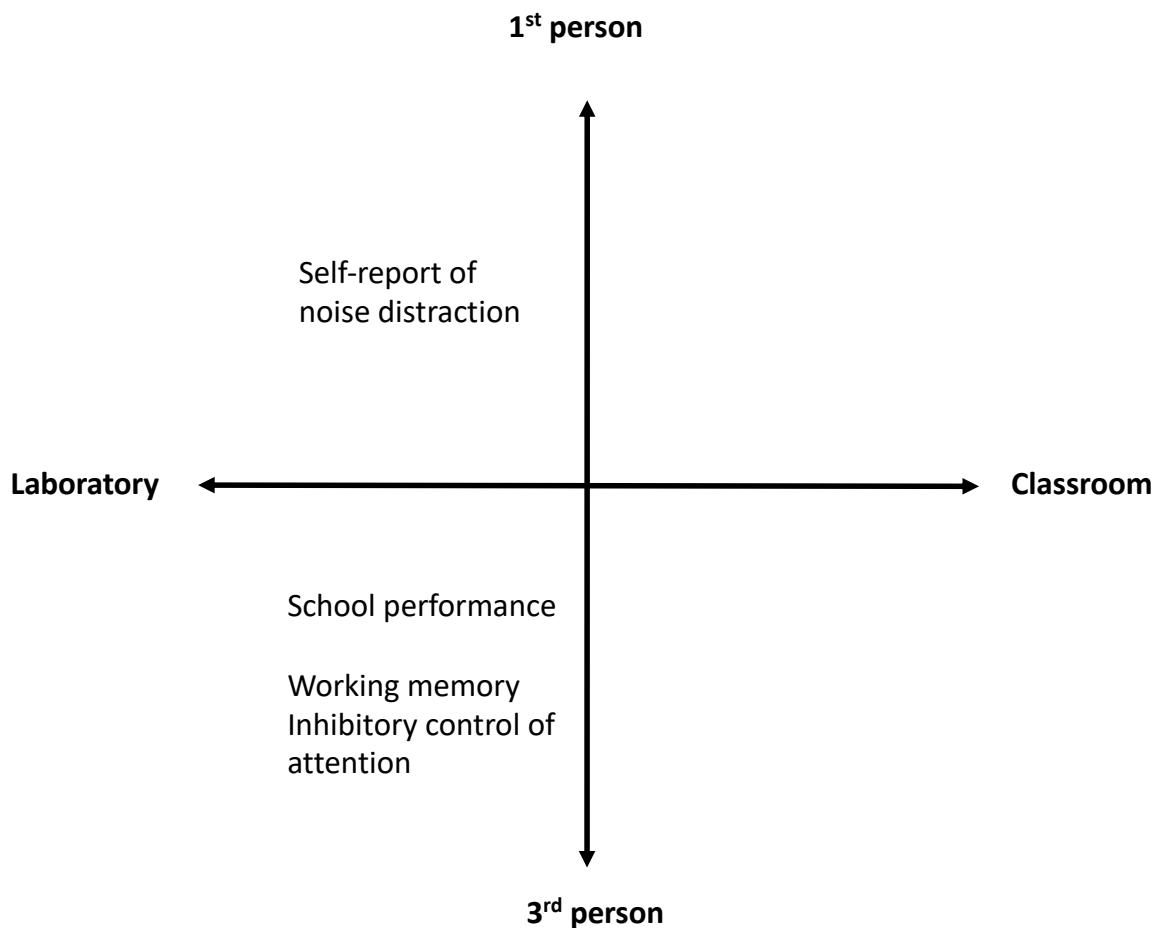


Figure 2.1. Methodological approach used in Chapter 2

2.2. Experiment 1: Comparing the impact of verbal and mixed classroom noise on academic performance, and its modulation by executive functions

2.2.1. Introduction

This chapter focuses on three types of school outcomes: text recall, reading comprehension, and mathematics.

Memory is a highly valued ability in school: children are exposed to new facts, words, ideas. Remembering them, and integrating them into coherent mental representations is one of the building blocks of their developing understanding of the world.

The presence of moderate verbal noise has been shown to impair children's capacity to remember information in the short-term. Existing studies on primary school pupils focused on serial recall, asking participants to remember lists of objects, words, or numbers. Results show a detrimental impact of background noise composed of lists of words (Elliott, 2002; Elliott & Briganti, 2012) and foreign speech (Klatte, Lachmann, Schlittmeier, et al., 2010; Klatte et al., 2007). Two studies, on middle school pupils (Boman, 2004) and adults (Sörqvist, Ljungberg, et al., 2010) showed a negative impact of verbal noise on text recall. Hygge (2003) found no effect of multi-talker foreign speech on 12- to 14-year-olds' text recall and recognition. However, the noise was composed of two overlapping stories in a foreign language so it is possible that only noise including bits of conversations in the native language of the participants has a negative impact on text recall, as suggested by a study on high-school students (Hygge et al., 2003). An extension on primary-school pupils would be needed.

There is a paucity of evidence regarding the impact of mixed noise on children's text recall. An adult study showed that mixed office noise without speech, displayed at 65dB, has a detrimental effect on text recall (Banbury & Berry, 1998). An extension of these studies with children is required.

Overall, both verbal noise and mixed noise have the potential to negatively impact memory, although more studies using school-like tasks (e.g. text recall) with primary school pupils are needed. When the focus moves from memory to reading and mathematics performance, verbal and mixed noise show different effects.

Verbal noise seems to impair children's reading and spelling performance, although only one study is available, on 8-year-olds (Dockrell & Shield, 2006). Results, however, are congruent with an adult study showing an impairment in reading comprehension when participants simultaneously hear a story through headphones (Sörqvist, Halin, et al., 2010). Both studies used moderate levels of noise. Mixed evidence has been reported for mathematics, with either a negative impact of background babble on 8-year-olds performance (Dockrell & Shield, 2006), or a non-significant impact of background storytelling on 8- to 9-year-olds, and 11- to 12-year-olds scores (Kassinove, 1972). Note that noise levels in the last study were quite high (70-80dB). Adults are impaired by speech in their native, or non-native language when performing an arithmetic task (Banbury & Berry, 1998).

Findings with mixed noise are even more puzzling. They reveal either a positive or a non-significant impact of noise on mathematics as well as on reading comprehension. Positive effects of moderate mixed noise have been reported on 8-year-olds reading and spelling

performance (Dockrell & Shield, 2006), but non-significant effects on 12- to 13-year-olds reading performance were found in studies using recorded moderate noise (Ljung et al., 2009), or natural noise between 55 and 80dB occurring from adjacent rooms (Slater, 1968). Similar contradictory results have been reported on mathematics. Comparing moderate mixed noise to quiet, Dockrell and Shield (2006) and Ljung et al. (2009) found no significant difference in 8-year-olds, and 6- to 11-year-olds mathematic performance. However, seven-year-old children performed better when mixed noise was displayed at 70dB, compared to 65dB (Zentall & Shaw, 1980). Finally, a gender effect was reported when 6- to 11-year-olds were tested on a reasoning task. Boys performed better, but girls performed worse, in the presence of 70dB of classroom noise, as compared to a quiet condition (Christie & Glickman, 1980). Results on children contrast with one study on adults showing worse arithmetic performance in conditions of moderate mixed office noise (Banbury and Berry, 1998).

To summarise the existing evidence regarding verbal and mixed noise, both seem to have a negative impact on memory. Differential effects have been found for reading and mathematics. Verbal noise seems to have a negative impact on children's reading skills, but not necessarily on their mathematic performance. Mixed noise either has a positive, or a non-significant impact on both reading and mathematics. These findings are summarised in Table 2.1.

Table 2.1. Summary of the literature about the impact of verbal and mixed noise on performance at memory, reading, and mathematics tasks

	Verbal noise	Mixed noise
Memory	Mostly Negative	Mostly Negative
Reading	Negative	None, or Positive
Mathematics	None, or Negative	None, or Positive

How can this diversity of effects be explained? Let's recall the three main theories that have been proposed to account for the impact of noise on performance: 1) Order processing (Jones et al., 1993), 2) Phonological/Semantic processing (Neely & LeCompte, 1999; Salamé & Baddeley, 1982), and 3) Attention capture (Hughes et al., 2007; Mehta et al., 2012).

The order processing account claims that when the background noise contains *changing-state* characteristics, such as a series of distinct, successive sounds, it is perceived as ordered. Some tasks that participants are required to perform under noisy conditions, such as remembering lists, also involve the processing of order. The processing of order from the two streams of information would then interfere, resulting in lower performance. This interpretation has mostly been used in the context of laboratory studies showing impairment in serial recall in noisy conditions. The interference by order processes account can also explain the non-significant effects of mixed noise on reading and mathematical performance, since mixed noise contains an irregular superposition of noise stimuli, without a specific order. However, it does not explain the negative impact of mixed noise on memory, or its positive impact on reading and mathematics. It is also difficult to understand the negative impact of verbal noise

on tasks which do not rely on the strict, ordered processing of information (e.g. reading comprehension).

Other theories focus on phonological and/or semantic processing instead of order processing. According to the phonological account, reading or being presented with visual representations would lead to an active rehearsal of phonological information. Hearing speech also involves the processing of phonological information, and both streams would interfere with each other. Semantic processes could also be involved when both the sound and the task at hand contain meaningful speech. The phonological/semantic processing account explains the detrimental impact of verbal noise on reading performance, and on the memory for verbal information. However, it is hard to understand why mixed noise does not impact text recall and text comprehension to the same extent (both tasks involving the processing of phonological information), and why it could have positive effects on reading and mathematics.

A third theoretical account highlights the role of attention capture when working in noisy conditions. According to Klatte et al. (2013), “auditory events that are salient (e.g., of personal significance, such as one’s own name), unexpected (e.g., slamming of a door), or deviant from the recent auditory context (e.g., change in voice in a speech stream) have a strong potential to capture attention.” (p.3). Attention, conceived as a limited resource, would then be less available for the main task. This could explain why verbal, and mixed noise have a negative impact on memory, as participants’ attention is being redirected away from the information to remember.

The only studies that have assessed attentional skills and whether they modulate the impact of noise have involved adults, and have often merged the constructs of working memory and inhibitory control, which are distinguished in the executive function literature (Diamond, 2013; Miyake et al., 2000). Working memory is the ability to store and manipulate information that is no longer perceptually present. Inhibitory control allows people to resist distractors. Experimental studies in the noise literature show that better working memory skills are protective against the effects of verbal noise on serial recall (Sörqvist, 2010b), text recall (Sörqvist, Ljungberg, et al., 2010), and reading comprehension (Sörqvist, Halin, et al., 2010), but a closer look at the measures suggest that this protective effect might reflect a process of inhibitory control. For example, Sörqvist, Halin, et al. (2010)'s working memory test involved having participants identify and remember the three smallest numbers in a list. The mediation effect observed was explained by the ability to suppress irrelevant numbers immediately from memory.

Can attentional processes explain the counterintuitive positive impact of mixed noise on reading and maths performance? Why would the redirection of attention not be detrimental for these tasks as well? A partial answer comes from the creativity literature. Mehta et al. (2012) asked adult participants to generate multiple ideas and/or find links between words. Participants who were exposed to 70dB of mixed noise gave more original answers, compared to those exposed to low noise (50dB) and high noise (80dB). Crucially, this positive effect was associated with a feeling of being distracted and less able to concentrate in comparison to lower levels of noise. According to the authors, this disruption leads to more abstract processing, enhancing conceptual associations and creative thinking. Disruption under high

noise levels (80dB) would not be beneficial because participants spend less time on the task (maybe to reduce their exposure to noise).

These results could transfer to school tasks such as reading comprehension and mathematics, if learning and creativity are considered intertwined processes (Guilford, 1967). Idea generation could, for example, help children to imagine what might follow a particular event in a story, or to make inferences. Similarly, in mathematics, idea generation could be used to redefine problems, or to find multiple ways to solve them (Beghetto & Kaufman, 2014; Pang, 2015). Moderate mixed noise could therefore provide the optimal amount of distraction to favour idea generation.

Experimental studies including measures of inhibitory control and working memory on child populations are clearly needed. This would not only be theoretically relevant, but also practically important, since it could help advance our understanding of why children are differentially affected by noise in the classroom (e.g. because they have different levels of inhibitory control).

2.2.2. Aims of the current investigation

Experiment 1 has two main goals. The first is to compare the impact of verbal and mixed noise on children's performance on three school tasks: text recall, reading comprehension, mathematics. In order to disentangle the main factors responsible for the effects of noise, both types of noise were displayed at moderate levels, but only the verbal noise contained salient meaning. The second goal is to test whether the impact of noise was modulated by

working memory and/or inhibitory control. To avoid confusion between the two constructs, two separate measures, one of working memory (the backward digit span task), one of inhibitory control (the Flanker task) were used.

It was predicted that both verbal noise and mixed noise would have a negative impact on text recall. Verbal noise was hypothesised to be detrimental for reading comprehension, but not for mathematics. Mixed noise was predicted to have no impact, or a positive impact on reading comprehension and mathematics. The impact of noise was predicted to interact with children's inhibitory control.

Children in their late primary school years were recruited for two main reasons. First, working memory and inhibitory control can be distinguished as two different factors for children of this age range (Brydges et al., 2014). Second, this allows focus on fluent readers. Important variations in reading abilities at the beginning of primary school might drive the effect of verbal noise - children could be particularly impaired because of their difficulties to process phonological and semantic information, whatever their level of working memory or inhibitory control.

2.2.3. Methods

2.2.3.1. Participants

Sixty-five children were recruited from nine different classrooms. Children were at the end of Year 4 ($n = 11$), in Year 5 ($n = 24$), or at the beginning of Year 6 ($n = 30$). Data from one child

(in Year 4), whose parents indicated hearing impairment, were subsequently removed from the analyses. The final sample included 64 children between 8.82 and 11.40 years of age ($M = 10.23$; $SD = .67$). The project received ethical approval from both the Departmental and College Ethics Committees. Following an opt-in procedure, all the participants gave verbal consent to participate, and written informed consent was obtained from their guardian. The study was conducted in accordance with the Declaration of Helsinki.

2.2.3.2. Procedure

Testing occurred in a quiet room in school, during two sessions, within a two-week period. *Session A* included a test of inhibitory control, and three school tasks assessing text recall, reading comprehension and mathematical performance. *Session B* included a measure of verbal working memory, and parallel versions of the tasks evaluating text recall, reading comprehension and mathematics. Within *Session A*, inhibitory control was always measured first, in silence. Within *Session B*, working memory was also measured first, in silence. The school tasks were then presented in a random order (see Table 2.2). To make sure that the amount of noise exposure would be comparable for all three tasks, each of them was designed to last for 7 minutes 30 seconds. Each session, including a presentation of the experiment at the beginning, and a debriefing session at the end, lasted between 30 and 40 minutes. The order in which *Session A* and *Session B* were presented was counterbalanced across participants. One set of school tasks was performed in silence, the other set in noise. Whether the first session was in silence or in noise was also counterbalanced between participants.

Table 2.2. Content of the testing sessions in Experiment 1

Session A	Session B
Inhibitory control	Working Memory
Text Recall	Text Recall
Reading Comprehension	Reading Comprehension
Mathematics	Mathematics

Tasks in grey were presented in a random order.

This study uses a mixed-design: all children were tested in silence and in noise, but the type of noise (verbal noise or mixed noise) varied between participants. Thirty-three children were tested with verbal noise, 31 children were tested with mixed noise.

The verbal noise was created by recording a female, fluent English speaker, who narrated three different children's stories. Each story lasted 7 minutes 30 seconds, to match the duration of each school task. The order of the three stories was constant, but since the order of the school tasks was counterbalanced, each specific combination of story and school task was used. This was to make sure that the impact of noise on a given task was not due to the particular content of the story, but to the general verbal nature of the noise. The noise was played at 60 dB(A) on average ($L_{Aeq}(7 \text{ min } 30) = 65\text{dB}$; Range 50-81 dB(A); see Figure 2.2. for a visual representation) through head-mounted headphones.

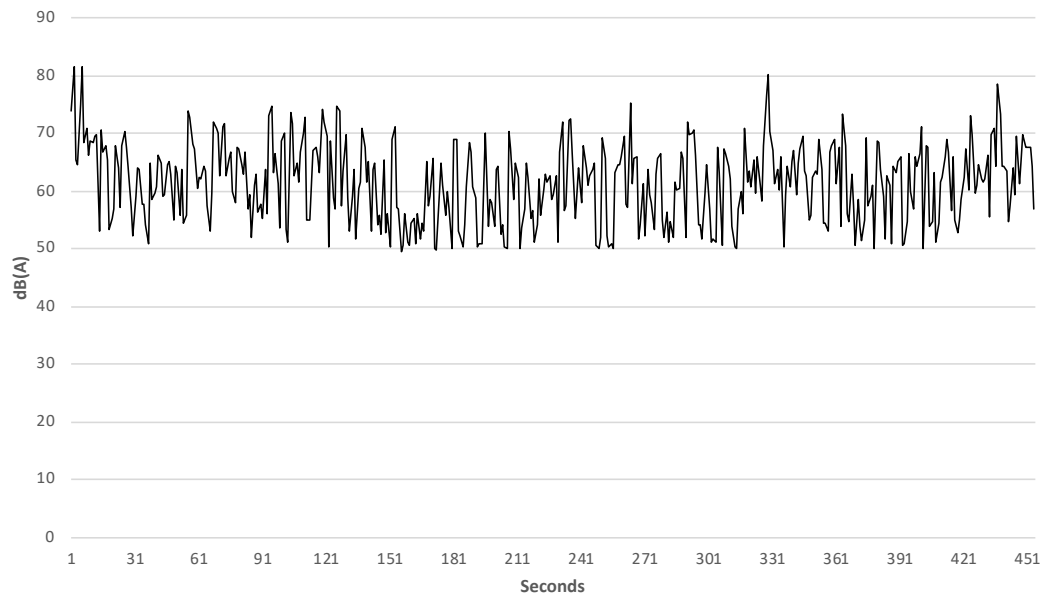


Figure 2.2. Sound pressure levels (A-weighted decibels) of the verbal noise over time

The mixed noise consisted of recordings of classroom noise, including bits of conversation, movement noise and outside noise. The verbal meaning of the conversations was difficult to perceive, since the different sources of noise were overlapping. Three different samples were created, each lasting 7 minutes 30 seconds, to match the duration of each school task. The order of the three sound files was fixed, but since the order of the school tasks was counterbalanced, each specific combination of sound file and school task was used. The noise was played at 60 dB(A) on average ($L_{Aeq}(7 \text{ min } 30) = 65\text{dB}$; Range 50-80 dB(A); see Figure 2.3 for a visual representation) through head-mounted headphones.

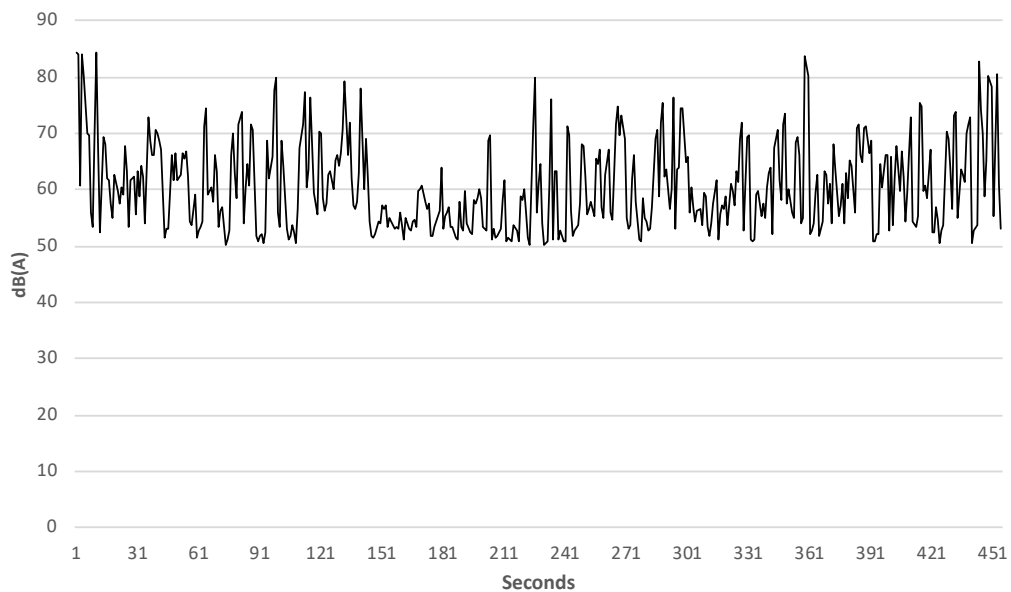


Figure 2.3. Sound pressure levels (A-weighted decibels) of the mixed noise over time

Note that the overall sound pressure levels were matched for the two types of noise, and that similar variations in decibels across time occurred in both types of noise, as shown in Figures 2.2 and 2.3.

During the silent testing session, pupils worked quietly. They were exposed to noise naturally occurring from outside of the testing room, ranging from 35 to 45dB. This exposure, corresponding to low levels of noise, was further reduced by the use of noise cancelling headphones (Noise Reduction Rating of 34dB; ANSI S3.19 and CE EN352-1 Approved).

2.2.3.3. Measures

All the measures were computerised and programmed using an online experiment builder, Gorilla.sc (<https://gorilla.sc/>).

Verbal working memory was assessed with the *backward digit span* task, available at <https://gorilla.sc/openmaterials/36699>. Children were presented with lists of digits on the computer screen, and were asked to repeat them backwards by clicking on an answer pad. For each trial, a fixation cross was displayed in the centre of the screen (450 ms), followed by a blank screen (500 ms). A digit was then presented at the centre of the screen for 1500 ms, followed by another blank screen of 500 ms. This procedure was repeated until the list length was reached. Once the full list was presented, children had to repeat the digits backward, by clicking on an answer pad with the mouse. The answer pad was displayed on the right-hand side of the screen (see Figure 2.4). Children started with two practice trials, with a list length of two (e.g. they were presented with “2, 5”, and had to answer “5, 2”). Immediate feedback was provided: A red cross was displayed if children answered incorrectly, and a green tick was shown if they answered correctly. Instructions were clarified by the experimenter if necessary. Following the practice, five lists of two digits were presented. Children had to succeed on at least four lists to move on to the next level. This procedure was repeated until children could not progress onto the next level (e.g. children who succeeded at four or five lists of three digits moved on to lists of four digits, the other children stopped the task). The final score corresponded to the total number of correct trials.

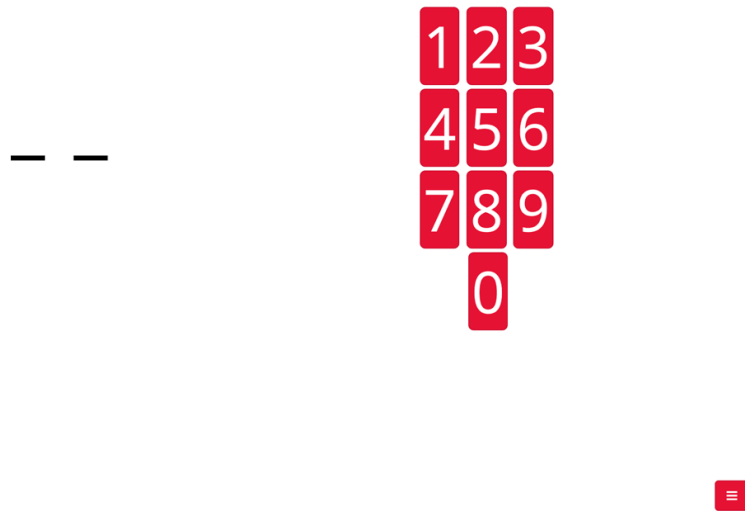


Figure 2.4. Response screen for the backward digit span task

Inhibitory control was assessed with a Flanker task (Anwyl-Irvine, Massonnié, Flitton, Kirkham, & Evershed, 2019), available at <https://gorilla.sc/openmaterials/36172> and adapted from Rueda et al. (2004). A horizontal row of five cartoon fish was presented in the centre of the screen, and participants had to indicate the direction the middle fish was pointing (either to the left, or right), by pressing the “X” or “M” buttons on the keyboard. These buttons were selected so that children could put one hand on each response key. Buttons were covered by arrows stickers (left arrow for “X”; right arrow for “M”) to avoid memory load. The task had two trial types: *congruent* and *incongruent*. In *congruent* trials, the middle fish was pointing in the same direction as the flanking fish. In the *incongruent* trials, the middle fish was pointing in the opposite direction. For each trial, a fixation cross was displayed for 1700 ms, followed by the presentation of the fish stimuli, which stayed on screen until a valid response was provided. Participants were asked to answer as quickly and accurately as possible. A blank screen was displayed before the next trial, its duration varying randomly between 400, 600, 800 and 1000 ms.

After the experimenter had introduced the task, there were 12 practice trials, with immediate feedback on the screen. A red cross was displayed if children answered incorrectly, and a green tick was shown if they answered correctly. Instructions were clarified by the experimenter if necessary. After the practice trials, four blocks of 24 trials each were presented. Self-paced breaks were provided between the blocks. For each participant, 50% of the trials were congruent, and the direction of the middle fish varied randomly between left and right. Four types of trials were therefore presented (see Figure 2.5): all the fish pointing to the right (25%), all the fish pointing to the left (25%), middle fish pointing to the right and flanking fish to the left (25%), middle fish pointing to the left and flanking fish to the right (25%). Accuracy (the proportion of correct trials) and Reaction Times for correct answers (RTs) were recorded.

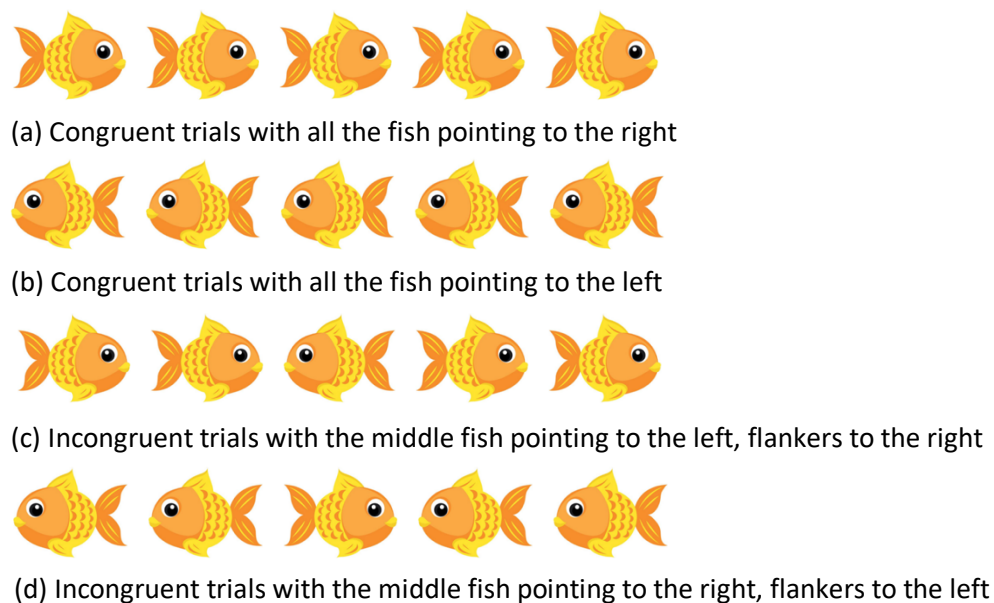


Figure 2.5. Trial types in the Flanker task

In the **text recall** task, children were presented with a 545-words narrative text and had 4 minutes 30 seconds to read it. They were then asked 6 successive questions, presented for

30 seconds each. The questions assessed memory of literal information (short bits of information that are directly stated in the text). One point was awarded per correct answer. Two raters scored each answer. The intra-class correlation coefficient was high, reaching .94 for the text in *Session A*, and .97 for the text in *Session B*).

Reading comprehension was assessed with two texts. First, pupils read a 114-words narrative text and answered a comprehension question. Both the text and the question were displayed at the same time, to avoid overloading memory, during 3 min 45 seconds. A second, 141-word narrative text was then presented with its accompanying question for 3 min 45 seconds. Each question was scored 0, 1, 2 or 3, depending on whether the answer was correct, and how much justification from the text was provided. The maximum score per session was 6. Two raters scored each answer. The intra-class correlation coefficient was high, ranging between .85 and .93 depending on the text, with an average of .89.

Mathematics performance was measured with 12 short questions, related to the core curriculum themes of: ordering numbers, addition, subtraction, multiplication, division, fractions, measurement, geometry, statistics. Questions were adapted from a traditional school book (Pearce, 2014), based on the skills that are expected to be mastered by the end of the first term, in Year 5. Children were told they had 37.5 seconds to answer each question. This duration was calculated by dividing the total duration of the task by the number of questions. It was piloted with 5 children to ensure it allowed them sufficient time to answer. There was no timer on the screen. One point was given per correct answer. A time-out was scored zero.

Two versions of each school task were designed, corresponding to *Session A* and *Session B*. Each task lasted 7 minutes 30 seconds. The full material and scoring rules are presented in Appendix A.

A self-report measure of noise distraction was included at the end of the noisy session. Children were asked whether they found the noise Not at all (1), A bit (2), or Very distracting (3). They were also invited to comment openly on their answer.

2.2.4. Results

2.2.4.1. Pre-processing of the Flanker task

Accuracy was at ceiling for both the congruent ($M = 97.95\%$) and the incongruent ($M = 96.45\%$) trials. Therefore, reaction times for correct answers (RTs) were retained as the main outcome of interest. RTs under 200ms (too short to follow the perception of the stimuli), and above 3 standard deviations from the mean of each subject were excluded (see Koivisto & Grassini, 2016; Rutiku, Aru, & Bachmann, 2016; Whelan, 2008).

Furthermore, extreme values were identified for one participant: their RTs for congruent trials and incongruent trials were 3.97 and 6.67 standard deviations away from the mean of the sample respectively. The difference in RTs between congruent and incongruent trials for this participant was also 7.37 standard deviations away from the mean. To avoid this outlier from driving the results, its scores were removed from further analyses of the Flanker task.

An analysis of variance, with Congruency (Congruent trials vs Incongruent trials) as a within-subject factor, and Age as a covariate, was carried out. There was a significant main effect of Congruency ($F(1, 61) = 15.04, p < .001, \eta^2_p = .20$) as well as a significant interaction with Age ($F(1, 61) = 13.71, p < .001, \eta^2_p = .18$). Overall, RTs were longer for incongruent trials ($M = 844.00; SD = 161.06$) compared to congruent trials ($M = 822.64; SD = 138.61$), but this difference diminished with age ($r = -.43; p < .001$).

Reaction time costs (RTs incongruent trials - RTs congruent trials) were used as the main measure of inhibitory control in subsequent analyses. Higher values indicate poorer inhibitory control, since it takes longer to give the correct answer for incongruent trials compared to congruent trials.

2.2.4.2. Descriptive statistics and correlations

Descriptive statistics are reported in Table 2.3. Due to a technical error, data were missing for two children in the text recall task (one corresponding to the silent session, one to the noisy session). Independent T-tests were carried out to test whether participants in the verbal noise and mixed noise conditions differed in terms of Age, Working Memory, Flanker performance and academic performance (measured in silence). The assumption of equality of variance between the two groups was tested with the Levene's Test. No violation was identified. Children in the verbal noise condition were older ($t(62) = -5.78, p < .001$) and had a smaller Flanker effect ($t(61) = 2.68, p = .009$) than children in the mixed noise condition.

Table 2.3. Descriptive statistics in Experiment 1

	Verbal noise		Mixed noise		Full sample	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Age	10.61 ^a	.54	9.82 ^a	.55	10.23	.67
Working Memory	9.76	5.87	11.90	4.83	10.80	5.46
Flanker	.36 ^a	72.01	43.02 ^a	52.39	21.35	66.20
(Silence) Text Recall	2.79	1.71	2.77	1.55	2.78	1.62
(Silence) Reading comprehension	2.30	1.88	2.29	1.99	2.30	1.92
(Silence) Maths	6.27	3.02	5.61	3.04	5.95	3.03
(Noise) Text Recall	2.64	1.58	2.67	1.56	2.65	1.56
(Noise) Reading comprehension	2.36	1.87	2.32	1.70	2.34	1.77
(Noise) Maths	5.85	3.41	5.71	3.25	5.78	3.31

^a Significant difference between participants in the verbal noise and mixed noise conditions.

Correlations between variables are reported in Table 2.4. Older children had better inhibitory control, higher reading comprehension and mathematics scores when tested in silence. They also had higher reading comprehension scores when tested in noise. Scores at the three school tasks were positively correlated to each other. Furthermore, for each school task, the score in silence was positively correlated with the score in noise.

Correlations controlling for age showed that better working memory was associated with better inhibitory control (weaker Flanker effect). Better working memory was also associated with better performance on the three school tasks (whether children were tested in silence

or in noise). Better inhibitory control was only related with better performance in mathematics (tested in silence or in noise).

Table 2.4. Correlations between all the variables in Experiment 1

	2	3	4	5	6	7	8	9
1. Age	-.05 <i>p</i> = .68	-.43 <i>p</i> < .001	.10 <i>p</i> = .44	.30 <i>p</i> = .02	.27 <i>p</i> = .03	.11 <i>p</i> = .38	.32 <i>p</i> = .01	.24 <i>p</i> = .06
2. WM		-.18 <i>p</i> = .16	.28 <i>p</i> = .02	.30 <i>p</i> = .02	.33 <i>p</i> = .01	.40 <i>p</i> = .001	.33 <i>p</i> = .01	.43 <i>p</i> < .001
3. Flanker	-.27 <i>p</i> = .04		-.13 <i>p</i> = .33	-.22 <i>p</i> = .09	-.40 <i>p</i> = .001	.04 <i>p</i> = .75	-.30 <i>p</i> = .02	-.39 <i>p</i> < .01
4. (Silence) Text recall	.29 <i>p</i> = .03	-.10 <i>p</i> = .46		.61 <i>p</i> < .001	.45 <i>p</i> < .001	.44 <i>p</i> < .001	.41 <i>p</i> = .001	.43 <i>p</i> < .001
5. (Silence) RC	.35 <i>p</i> = .01	-.10 <i>p</i> = .48	.61 <i>p</i> < .001		.39 <i>p</i> = .001	.41 <i>p</i> = .001	.50 <i>p</i> < .001	.44 <i>p</i> < .001
6. (Silence) Maths	.37 <i>p</i> < .01	-.32 <i>p</i> = .01	.45 <i>p</i> < .001	.35 <i>p</i> < .01		.35 <i>p</i> = .004	.42 <i>p</i> = .001	.84 <i>p</i> < .001
7. (Noise) Text recall	.41 <i>p</i> = .001	.10 <i>p</i> = .46	.43 <i>p</i> < .001	.41 <i>p</i> = .001	.34 <i>p</i> < .01		.27 <i>p</i> = .03	.39 <i>p</i> = .001
8. (Noise) RC	.38 <i>p</i> < .01	-.19 <i>p</i> = .16	.40 <i>p</i> = .001	.44 <i>p</i> < .001	.37 <i>p</i> < .01	.25 <i>p</i> = .05		.43 <i>p</i> < .001
9. (Noise) Maths	.46 <i>p</i> < .001	-.33 <i>p</i> = .01	.42 <i>p</i> = .001	.41 <i>p</i> = .001	.83 <i>p</i> < .001	.38 <i>p</i> < .01	.39 <i>p</i> < .01	

RC: Reading comprehension; Upper triangle shows first-order correlations, lower triangle shows correlations controlling for age.

2.2.4.3. The effect of noise on academic performance

For each school task, a Multivariate analysis of covariance (MANCOVA) was performed. Condition was the dependent, within-subject factor (Silence vs Noise). First order interactions with the Type of Noise (Verbal vs Mixed), Session Order (Session A first vs Session B first), Condition Order (Silence First vs Noise First), School Task Order (First, Second, Third) and Age (entered as continuous covariate) were tested. Since children tested with verbal noise were older than those tested with mixed noise, a three-way interaction between Condition, Type of Noise and Age was also entered in the model.

Text recall

There was no main effect of Condition ($F(1, 54) = .01, p = .930, \eta^2_p = .000$) and no interaction with the Type of Noise ($F(1, 54) = .19, p = .669, \eta^2_p = .003$), or with Age ($F(1, 54) = .12, p = .912, \eta^2_p = .000$). However, the effect of Condition interacted with the Condition Order ($F(1, 54) = 5.60, p = .022, \eta^2_p = .094$). Follow-up paired *T*-tests showed that performance in noise was worse than in silence only when participants were tested in the noisy session first ($M_{\text{Noise}} = 2.58; M_{\text{Silence}} = 3.23; t(29) = 2.33, p = .027$). Participants tested in silence first did not significantly perform worse in noise ($M_{\text{Noise}} = 2.72; M_{\text{Silence}} = 2.34; t(31) = -1.33, p = .195$). As can be seen with these descriptive statistics, and with follow-up independent *T*-tests, children's performance in silence was better when it was the second session ($t(61) = -2.23, p = .03$), whereas performance in noise did not change whether it was presented first or second ($t(61) = .35, p = .728$). The effect of noise did not interact with any other counterbalancing factor (Session Order, School Task Order).

The main effect of Condition Order almost reached significance ($F(1, 54) = 3.87, p = .054, \eta^2_p = .067$), indicating that, overall, performance was better for children who were tested in noise first ($M = 2.92$), compared to those who were tested in silence first ($M = 2.53$).

Furthermore, School Task Order had an overall effect on performance ($F(2, 54) = 5.24, p = .008, \eta^2_p = .162$). A follow-up One-way ANOVA with a Tukey post-hoc test showed that performance at text recall was lower when the task was presented in the middle of the testing session ($M = 1.97$) compared to when it was presented last ($M = 3.02; p = .037$). Performance when the task was presented first ($M = 2.86$) did not significantly differ from the second ($p = .132$) or third ($p = .917$) positions.

Finally, overall, older children had better performance at the text recall task ($F(1, 54) = 5.5, p = .023, \eta^2_p = .092$; see Table 2.4 for the correlations).

Reading comprehension

There was no main effect of Condition ($F(1, 56) = .03, p = .874, \eta^2_p = .000$), and no interaction with the Type of Noise ($F(1, 56) = .006, p = .939, \eta^2_p = .000$), with Age ($F(1, 56) = .02, p = .877, \eta^2_p = .000$) or any of the three counterbalancing factors (Condition Order, Session Order, School Task Order). Overall, and as shown in Table 2.4, older children had higher reading comprehension scores ($F(1, 56) = 16.47, p < .001, \eta^2_p = .227$).

Mathematics

There was no main effect of Condition ($F(1, 56) = .01, p = .919, \eta^2_p = .000$), and no interaction with the Type of Noise ($F(1, 56) = .25, p = .620, \eta^2_p = .004$), or with Age ($F(1, 56) = .01, p = .905, \eta^2_p = .000$). The effect of Condition interacted with the Condition Order ($F(1, 56) = 9.49, p = .003, \eta^2_p = .145$). Follow-up paired t-tests showed that performance in noise was

worse than in silence only when participants were tested in the noisy session first ($M_{\text{Noise}} = 5.44$; $M_{\text{Silence}} = 6.28$; $t(31) = 2.60$, $p = .014$). Participants tested in silence first did not significantly perform worse in noise ($M_{\text{Noise}} = 6.13$; $M_{\text{Silence}} = 5.62$; $t(31) = -1.83$, $p = .077$). Independent T-tests showed that neither the performance in silence ($t(62) = -.87$, $p = .390$) nor in noise ($t(62) = .83$, $p = .410$) significantly differed as a function of whether it was presented first or second. The effect of noise did not interact with any other counterbalancing factor (Session Order, School Task Order).

2.2.4.4. Modulation of the effect of noise by working memory and inhibitory control

Further analyses were carried out to investigate whether there was any interaction between the effect of Noise and Working Memory or Flanker Performance. For each school task, the same variables as in 2.2.4.3. “The effect of noise on academic performance” were entered into a MANOVA, but the factors Working memory and Flanker performance were added as a covariate, in two successive analyses. Since Condition Order interacted with the effect of Condition for the text recall and mathematics tasks, a three-way interaction between Condition, Condition Order and Working memory / Flanker performance was added to the analyses. This allowed us to investigate whether working memory and inhibitory control modulated the negative impact of noise on performance (occurring when the noisy session was first).

Text recall

Although there was a main effect of Working Memory ($F(1, 52) = 8.26$, $p = .006$, $\eta^2_p = .137$), it did not interact with the effect of Condition ($F(1, 52) = 1.32$, $p = .256$, $\eta^2_p = .025$). In

other words, better working memory was associated with better performance in text recall (see the correlations in Table 2.4), but it did not explain the difference in performance between the silent and noisy sessions. There was no three-way interaction between Condition, Condition Order and Working Memory ($F(1, 52) = .38, p = .54, \eta^2_p = .007$).

There was no main effect of Flanker performance ($F(1, 51) = .39, p = .535, \eta^2_p = .008$) on text recall. There was no simple interaction with Condition ($F(1, 51) = .75, p = .390, \eta^2_p = .015$), and no three-way interaction between Condition, Condition Order and Flanker performance ($F(1, 51) = 3.33, p = .074, \eta^2_p = .061$).

Reading comprehension

Although better Working Memory was associated with better performance ($F(1, 55) = 7.27, p = .009, \eta^2_p = .117$; see Table 2.4 for correlations), it did not interact with the effect of Condition ($F(1, 55) = .091, p = .763, \eta^2_p = .002$). There was no main effect of Flanker performance on reading comprehension ($F(1, 54) = 1.69, p = .199, \eta^2_p = .030$), and no interaction with Condition ($F(1, 54) = .73, p = .397, \eta^2_p = .013$).

Mathematics

Better Working Memory was associated with better mathematics performance ($F(1, 54) = 13.79, p < .001, \eta^2_p = .203$), see Table 2.4 for correlations. The effect of Condition interacted with Working Memory ($F(1, 54) = 4.71, p = .034, \eta^2_p = .080$). To shed light on this interaction, the difference in score between the silent and noisy session was calculated (Score in Silence – Score in Noise). The impediment due to noise tended to be smaller for children with higher working memory ($r = -.23, p = .067$). There was no significant three-way

interaction between Condition, Condition order and Working Memory ($F(1, 54) = 3.17, p = .081, \eta^2_p = .055$).

Better inhibitory control was related to better mathematics performance ($F(1, 53) = 6.01, p = .018, \eta^2_p = .102$), but there was no interaction with Condition ($F(1, 53) = 1.14, p = .291, \eta^2_p = .021$), and no three-way interaction between Condition, Condition Order and Flanker performance ($F(1, 53) = .079, p = .78, \eta^2_p = .001$).

2.2.4.5. Relation between the impact of noise on performance and children's subjective perception of being distracted.

Results from the MANOVAs reported above indicated that noise had a detrimental effect on text recall and mathematics performance when children were tested in noise first. However, for all the school tasks, there was inter-individual variability in the data. That is to say, some children performed better in silence, some performed better in noise, and some had similar scores in both conditions. How do these differences in the “objective” impact of noise relate to children's sensation of being distracted? For each of the three school tasks, a Kruskal-Wallis Test was performed to assess whether the difference in score between the silent and noisy session was related to children's answer at the noise distraction question. Results show that this was not the case for text recall ($\chi^2(2) = .90, p = .637$) and for reading comprehension: $\chi^2(2) = .95, p = .62$). Results for mathematics were significant ($\chi^2(2) = 6.37, p = .04$). Children who reported not being distracted at all had a *greater* impairment due to noise (a drop in performance of 1.45 points on average), compared to those reporting that they were a bit distracted (.26 more point in noise), or very distracted (.20 points in silence). Furthermore,

children's perception of being distracted did not relate to their performance at the working memory ($\chi^2(2) = 3.64, p = .162$) and Flanker tasks ($\chi^2(2) = .995, p = .608$).

The noise distraction question only had three possible closed answers. However, children's open comments about the noise provided more insight into their subjective reactions to noise, and how well these reactions matched the impact of noise on their school performance. Some children did feel distracted, and it showed on their scores. For example, a participant said that noise made it harder to concentrate, and they scored higher in silence for all three tasks (the difference was of 4 points for text recall, 2 points for reading comprehension, and 3 points for mathematics). In contrast, another participant reported that they were very distracted and could not stop listening to the noise during the recall task, when they actually performed slightly better in noise (the difference was only of 1 point, but was in the opposite direction than expected). Interestingly, this participant reported using strategies to avoid being too distracted, such as using the computer mouse to point at the words in the reading comprehension task – a task for which there was no difference in score between the silent and noisy sessions. Another child reported not being really distracted by noise because they managed to block it out. They actually performed slightly better in noise for all three tasks (again, a difference of only one point). Some children shared some positive impressions about the noise, saying that it prevented them from getting bored, or that silence was annoying. For some participants, being tested in silence in a school environment was “weird”, because silence is very rare in this type of setting.

2.2.5. Discussion

The present study investigated the impact of verbal noise and mixed noise on school performance, and whether this impact was modulated by children's working memory and inhibitory control.

Noise had a negative impact on mathematics performance, but only when the noisy session was carried out first or, in other words, when the silent session was second. Crucially, there was no significant difference between the effect of verbal and mixed noise. To our knowledge, only two other studies have directly compared the effect of verbal and mixed noise on mathematics performance. In the first study, three types of noise were used: verbal noise (a radio program), office noise without speech (keyboard, printer, telephone noise), and office noise with speech. These three types of noise had a similar negative impact on adult arithmetic performance (Banbury & Berry, 1998). In the second study, babble noise had a negative effect on 8-year-olds' performance compared to a quiet condition. But when the babble noise was embedded within environmental noise, children's performance was in between and not significantly different from either the quiet condition or the babble condition (Dockrell & Shield, 2006).

How could these different reported results be reconciled? In the Dockrell and Shield study (2006), as well as in other child studies showing either a non-significant (Kassinove, 1972; Ljung et al., 2009) or a positive effect (Zentall & Shaw, 1980) of noise on mathematics, pupils were tested in classroom-like situations, with paper and pencils at their disposal to perform calculations. However, in Experiment 1, as well as in Banbury & Berry (1998), questions were

presented on a computer screen, with no further support. This difference could have increased the task's memory requirements because participants needed to keep different elements in mind while performing the calculations. In fact, in both Experiment 1 and in Banbury & Berry (1998), the effect of noise on mathematics was similar to that on text recall, a task that draws heavily on memory.

Noise impaired children's memory for text only when the noisy session was presented first. This order effect was driven by scores in the silent session being higher (than in the noise session) when it was the second session. This could be due to a practice effect. Because children were familiar with the task, they could have developed strategies to try and recall key elements of the text. Performance in noise, however, was relatively similar for both presentation orders and did not seem to benefit from a practice effect. Maybe strategies are harder to implement in the presence of noise, and practice effects could be thwarted by the novelty effect of performing the task with recorded noise. However, these order effects remain unclear because they have not been found in adult studies using a within-subject design (Sörqvist, 2010a; Sörqvist, Ljungberg, et al., 2010).

As was the case with mathematics, there was no significant difference between the effect of verbal and mixed noise on text recall. To our knowledge, this is the first study testing the impact of both types of noise on children's text recall. Results are in line with those of adult studies showing a negative impact of verbal (Sörqvist, 2010a; Sörqvist, Ljungberg, et al., 2010) as well as mixed noise (Hygge et al., 2003) on similar tasks. In Banbury & Berry (1998)'s study, office noise without speech and office noise with speech impaired text recall to a similar

extent when they were presented in both the learning and recall phase, as was the case in the present study.

In contrast to the negative impact of noise on text recall and mathematics performance (when the first session was in noise), noise did not have a significant impact on reading comprehension. This stands in sharp contrast with the negative impact of verbal noise on adults' reading comprehension (Sörqvist, Halin, et al., 2010). Studies with children that were available when Experiment 1 was designed included measures of spelling skills (Dockrell & Shield, 2006), sentence completion tasks (e.g. filling gaps in sentences to make them meaningful; Dockrell & Shield, 2006; Ljung et al., 2009), or various reading skills (Slater, 1968), but did not focus on the comprehension of texts *per se*. These studies reported mixed findings, with a negative impact of verbal noise (Dockrell & Shield, 2006), a non-significant impact of multi-talker speech (Ljung et al., 2009), and a positive impact of mixed noise (Dockrell & Shield, 2006).

A recent paper (Connolly et al., 2019), published while Experiment 1 was being carried out, included a similar mixed noise condition and a similar task (e.g. a reading comprehension test minimizing memory demands by presenting questions immediately after the text). Two groups of participants, between 11 and 13 years of age, and between 14 and 16 years of age, were tested. Significant effects of moderate noise were limited to measures of reading time, word learning from a text, and literal reading comprehension (when the answers to the questions were explicitly contained in the text). No significant effects were found on inferential questions (when the answer had to be deduced from the text). The reading comprehension task in Experiment 1 focused on inferential understanding (in contrast with

the text recall task that only contained factual questions). Therefore, results from Experiment 1 were rather consistent with those from Connolly et al. (2019) although the children in Experiment 1 were younger, and the noise exposure was a bit longer (7 minutes 30 seconds vs 4 minutes 40).

In Experiment 1, verbal and mixed noise had a similar impact on each school task. Both types of noise were displayed at the same moderate level, with frequent variations in the sound pressure level over time. It is possible that these commonalities underlie the effect of noise on performance, despite the fact that verbal noise contained a salient verbal meaning absent from the mixed noise. Irregular noises might impact performance by capturing the participants' attention away from their ongoing task. This idea was tested by investigating interactions between the impact of noise on performance, and children's working memory and inhibitory control.

Children's inhibitory control was assessed with a Flanker task. Overall, better inhibitory control was related to better mathematics performance. This is in line with current educational theories suggesting that children need to suppress inappropriate strategies (e.g. an addition when a subtraction is required) or inappropriate answers (e.g., $3 \times 2 = 5$) to give correct answers (Cragg & Gilmore, 2014; Mareschal, 2016). However, children's inhibitory control did not mediate the impact of noise on performance. This goes against adult findings suggesting that better inhibitory control is protective when working in noisy conditions (Sörqvist, 2010b; Sörqvist, Halin, et al., 2010; Sörqvist, Ljungberg, et al., 2010). However, it is worth noticing that the negative impact of noise on text recall and mathematics in Experiment

1 *did not* correspond to a decrease in performance in noise, but to a better performance in silence when the silent session was second.

As with inhibitory control, working memory was related to better mathematics performance, whether it was assessed in silence, or in noise. To solve a mathematical problem, children need to keep multiple elements in mind (e.g. two sets of digits) while manipulating them (e.g. adding the digits). This is exactly what was involved in the backward digit span task used to measure working memory. Furthermore, children with lower working memory capacity were more impaired by noise when doing mathematics. To better understand this phenomenon, let's recall Baddeley (2003)'s model of working memory. The phonological loop would contain a phonological store holding memory traces for a few seconds. To avoid the memory traces fading, they would be refreshed by an articulatory process analogous to a subvocal speech. Performance at the backward digit span task, as well as efficient mental calculations could rely on a sub-vocal rehearsal of the digits to be manipulated. Since verbal and mixed noise both contained some phonological information, this information could also gain access to the phonological loop and interfere with subvocal rehearsal.

If noise interferes with mathematics performance via an interference with phonological processes, why didn't working memory modulate the impact of noise on reading comprehension and text recall as well? The backward digit span task could be particularly related to the impact of noise on mathematics because it tapped into very specific processes involved in the mathematics task (the storage and manipulation of digits). A working memory task with word stimuli could have potentially modulated the impact of noise on reading

comprehension and text recall, if the maintenance of word representations was crucial for performing these tasks.

Furthermore, the mathematics and reading tasks had different durations. Each mathematical problem was presented for 37 seconds. Participants therefore needed to quickly store and manipulate the digits in working memory, and provide an answer. Performance at the text recall and reading comprehension tasks might have involved both working memory and long-term memory. To understand and remember a text, children need to remember events presented at different moments and to understand how they relate to each other. By the time children were asked questions about the texts (after 7 minutes 30), performance might have relied on complex mental representations about the text, stored in long-term memory, and not only on immediate short-term memory (Gernsbacher et al., 1990). In other words, the meaning of the text stored in long-term memory would have been derived *after* the elements of the text were related in working memory.

These interpretations seem to contradict Sörqvist, Halin, et al. (2010) who found that performance on a working memory task involving the manipulation of digits predicted the impact of noise on reading comprehension. However, their reading comprehension task was based on short questions requiring a fast answer. Participants had to compare four different answers and select the appropriate one in 90 seconds. Participants had to remember the options and to compare them along with information from the text. In a similar set of experiments showing that better working memory was protective against the effects of noise on text recall (Sörqvist, Ljungberg, et al., 2010) or serial recall (Sörqvist, 2010b), the authors used a working memory task involving the manipulation of words, and/or a recall task in

which stimuli were presented very quickly (one minute or less). The memory demands were therefore higher than in Experiment 1, and the working memory measure shared more components with the recall tasks (since it involved the manipulation of words).

In sum, while the present study provides some insight into the causes of individual differences in the effect of noise on academic performance, it also highlights the need to consider the specifics of the task and of the noise stimuli carefully.

2.3. Conclusion and future directions

The current study is the first one to investigate the impact of both verbal and mixed noise on primary school students' reading comprehension, text recall, and mathematics performance. There was no significant difference in the effects of verbal and mixed noise. This might be due to similar fluctuations in sound pressure level over time in the two different types of noise. Noise either had a non-significant, or a negative impact on performance. Furthermore, inhibitory control did not explain inter-individual differences in the impact of noise, which questions the attention capture account.

A within-subjects design was used, with children in the verbal and mixed noise conditions matched according to baseline levels of reading comprehension, text recall and mathematics. Such a stringent control has rarely been used in the noise literature, and especially in studies showing *positive* effects of noise on performance, for which the attention capture account seemed the most suitable. Mehta et al. (2012) indeed suggested that moderate mixed noise would benefit creativity by inducing an optimal amount of distraction. They tested adults and

used a between-subject design with no matching criterion between participants exposed to different levels of noise. An extension of this work to a child sample, using a within-subject design, would be especially relevant. Moreover, Mehta et al. (2012) studied attentional processes by the means of self-report measures, which might not tap into the same cognitive processes as those involved in behavioural tasks of working memory and inhibitory control.

Therefore, Chapter 3 will investigate the impact of moderate mixed noise on children's idea generation skills, and its potential modulation by executive functions.

Chapter 3 - Testing the impact of mixed classroom noise on
creativity, and its modulation by executive functions

3.1. Chapter overview⁴

Chapter 3 extends the within-subjects design used in Chapter 2 to study the impact of moderate mixed noise on children's idea generation. Mehta et al. (2012) suggested that this type of noise would benefit creativity by inducing an optimal amount of distraction. However, this study focused on adults and used a between-subject design with no matching criterions between participants tested in different noise conditions. In classroom settings, the same children are exposed to different levels of noise within a day. Using a within-subject design is more stringent, methodologically speaking, and more naturalistic.

Furthermore, Mehta et al., (2012) measured participants' distraction with self-report questions. It is unclear how this would relate to behavioural measures of executive functions, as they have been used in experiments assessing interindividual differences in the effect of noise on performance. Chapter 2 suggested that self-report, and behavioural measures of attention might not reflect the same processes. Including both types of measures would allow for a better understanding of the mechanisms at play when working in noise.

In order to be able to perform direct comparisons with Experiment 1, in Experiment 2, children in their late primary school years were recruited. Their inhibitory control and working memory were assessed with similar tasks (e.g. Flanker task and backward digit span).

⁴ The work from this Chapter has been published in: Massonnié, J., Rogers, C. J., Mareschal, D., & Kirkham, N. Z. (2019). Is classroom noise always bad for children? The contribution of age and selective attention to creative performance in noise. *Frontiers in Psychology*, 10(381). <https://doi.org/10.3389/fpsyg.2019.00381>

However, because Experiment 2 was based on an opportunistic sample, younger children, in their early primary school years, were also included. Additional measures of executive functions were added (the Stroop task, assessing inhibitory control, and an adapted Corsi block task, assessing visuo-spatial working memory).

The approach used in this Chapter is shown in Figure 3.1. It includes a laboratory-based methodology, with a short question assessing children's subjective reaction to noise.

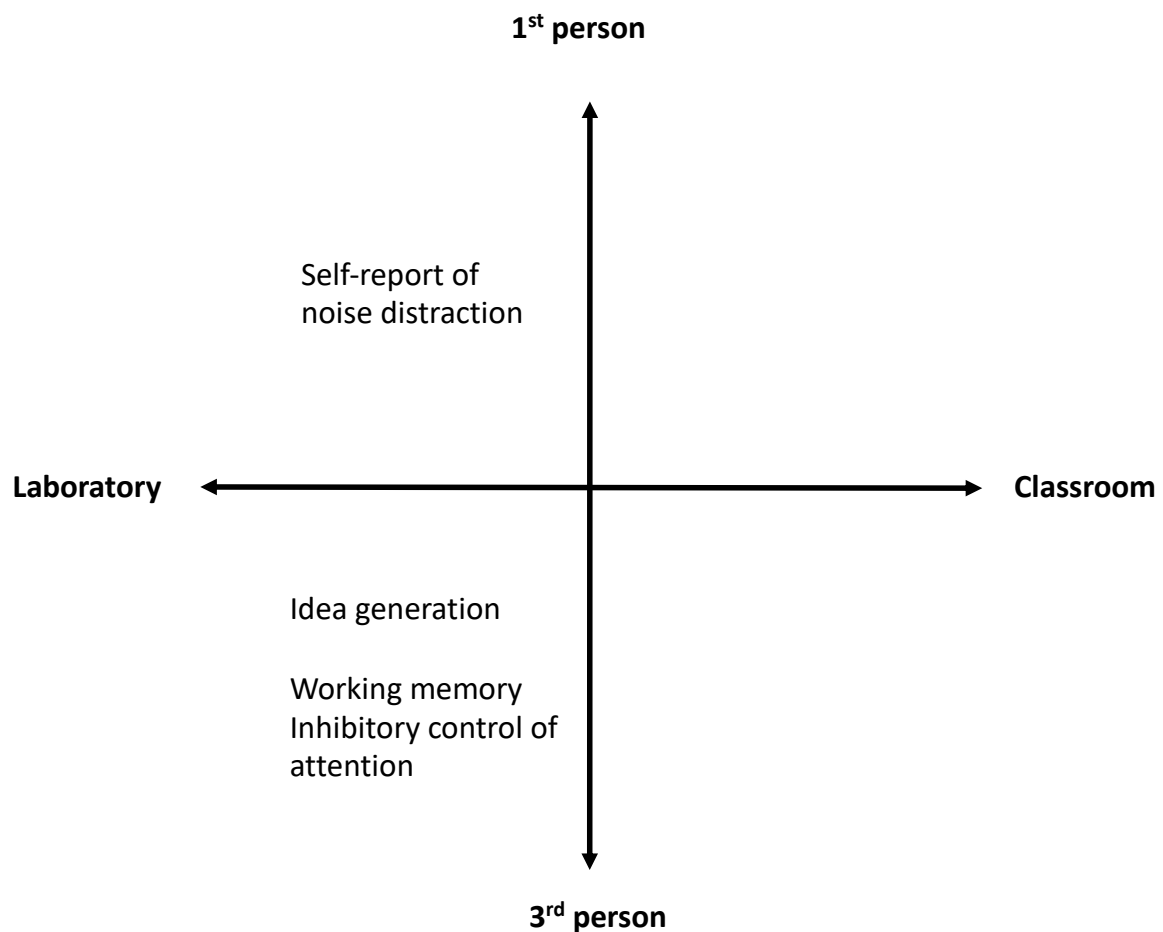


Figure 3.1. Methodological approach used in Chapter 3

3.2. Experiment 2: Testing the impact of mixed classroom noise on idea generation, and its modulation by executive functions

3.2.1. Introduction

Creativity involves the construction of new ideas and products, which are considered both original (unique) and of value (in other words, appropriate, or useful; Runco, 2003). Learning and creativity are intertwined processes that can both be cultivated in the classroom (Guilford, 1967). According to Pang (2015), idea generation (the process of creating new and potentially useful ideas) can be seen as a part of learning, in that it induces a change in a person's knowledge or behaviour. This process of making new connections and transformations between different elements of knowledge can positively impact learning in many areas of the curriculum. For example, idea generation during a reading session in the classroom might encourage children to imagine a brand new storyline or to suggest what might follow a particular event in a story (Pang, 2015). Similarly, in mathematics, idea generation can be used to redefine problems, or to find multiple ways to solve them (Beghetto & Kaufman, 2014; Pang, 2015). Idea generation is central to what children do at school.

Research on creativity has generally focussed on the cognitive processes and personality traits associated with creative thought (i.e., intelligence, knowledge base, risk-taking, openness to experience, motivation, etc.; Barbot, Lubart, & Besançon, 2016; Guilford, 1967; Runco, 2003; Sternberg, 2006; Sternberg & O'Hara, 1999). Studies looking at the environmental factors supporting creativity, in the classroom or in the workplace, tend to concentrate on social and

organizational factors such as the level and type of support provided by teachers/managers, the presence of collaborative settings, or access to relevant resources (Amabile, 1982; de Souza Fleith, 2000; Fasko, 2001; Shalley & Gilson, 2004). However, little is known about the *physical* environmental factors, including noise, that could influence creativity.

A recent paper by Mehta et al. (2012) explored the idea that a certain amount of ambient environmental noise might actually have a beneficial effect on creative processes. Using several canonical creative cognition tasks, in which participants had to generate multiple ideas and/or find links between words, Mehta et al (2012) discovered that adults' creativity was enhanced when in a moderate-noise environment (versus low noise or high noise). Dubbed the "Starbucks effect" this series of studies showed that when participants were exposed to noise of the level and type found in coffee shops (70dB, with varying traffic and speech sounds overlapped), they gave more original answers compared to participants working in low noise (50dB) and high noise (85dB) conditions. This leaves open the question as to whether noise is beneficial or detrimental to creative cognition in childhood.

In classrooms, noise levels range from 56dB during silent reading, to 76.8 dB during group work involving movement, with an average of 72dB during the school day (Shield & Dockrell, 2004). If one is trying to promote creativity by encouraging discovery learning and collaboration in the classroom (de Souza Fleith, 2000; Fasko, 2001), noise levels are likely to be between 70 and 76.8dB. These values are close to the "optimal" level of noise for creativity highlighted by Mehta et al. (2012). Crucially, Mehta et al. were keen to examine the effects of "real world" noise, and so used a mix of multi-talker voices, roadside traffic and distant construction noise in their study. This mixed noise is similar to the type of noise experienced

in classrooms, and more naturalistic than that previously used in research into noise and creativity (Hillier, Alexander & Beversdorf, 2006; Kasof, 1997; Martindale & Greenough, 1973).

Mehta et al. (2012) measured potential mechanisms by which noise might impact creativity, that is to say, participants' level of distractibility. In their study, the positive effects of moderate mixed noise on creativity was associated with a feeling of being distracted and less able to concentrate in comparison to lower levels of noise. A redirection of attention might therefore explain the effects of noise on creativity. Mehta et al. (2012)'s results are consistent with other recent findings that interrupting an on-going train of thought can lead to greater subsequent creativity (e.g., Baird et al., 2012; Wang, Ye & Teo, 2014). However, Mehta et al. (2012) used self-report measures of distractibility, and it is yet unclear how their findings would relate to experimental studies showing that executive functions (measured with behavioural tests) modulate the impact of noise on performance (Sörqvist, 2010b, Sörqvist, Ljungberg, et al., 2010, Sörqvist, Halin, et al., 2010).

Furthermore, it is worth mentioning that creativity itself (whether it is measured in silence or noise) might involve the use of executive function processes. In order to come up with original and useful ideas, participants have to manipulate, evaluate, and select information (Benedek, et al., 2014; Edl et al., 2014; Golden, 1975; Kleibeuker, De Dreu & Crone, 2016; Nusbaum & Silvia, 2011). Mehta et al. (2012) did not match participants who were exposed to different noise conditions, and it is possible that participants with higher executive functions, general knowledge or intelligence were over represented in the moderate noise conditions,

explaining its positive impact on creativity. Extending their findings using a within-subject design would rule out this explanation.

Moreover, if noise and creativity both tap into executive function resources, and given the protracted development of these skills over the course of development (Best & Miller, 2010; Diamond, 2013), it is possible that distraction from noise will be overwhelming for young children. Older children, by contrast, might behave more like adults, benefiting from noise interference, since they might have developed sufficient attentional resource to integrate distractions into the creative process.

3.2.2. Aims of the current investigation

Experiment 2 investigated the cognitive mechanisms by which mixed classroom noise might either increase or depress children's creativity. Specifically, it addressed three questions: 1) Do primary school children benefit from moderate amounts of mixed classroom noise when performing an idea generation task? 2) Does the effect of noise vary depending on children's age? 3) Is this effect modulated by attentional skills?

A within-subjects manipulation was used to assess the impact of noise on idea generation, with each child being tested in silence and noise. Unlike the between-subjects design used by Mehta et al. (2012), this design allowed for control of confounding variables, such as inter-individual differences in attention, when assessing the main effect of noise. In addition, this design was chosen to increase the ecological validity of the results as individual children in classrooms are exposed to varying levels of noise, depending both on time of day and the

kind of activity they are doing. It is unlikely that different groups of children are only exposed to one specific noise range.

The role of attention was assessed in two ways. First, to provide a developmental perspective, two groups of children were compared: those between 5 and 8 years old (early primary school / UK Key stage 1), and those between 8 and 11 years old (late primary school / UK Key stage 2). Secondly, behavioural assessments of both working memory and inhibitory control were included. This way, it was possible to directly assess whether inhibitory control was the main component modulating the impact of noise on creativity, independently, or in conjunction with age.

In accordance with Mehta et al.'s (2012) results, it was hypothesised that children would give more original ideas in the moderate mixed noise condition than in silence. This effect was expected to interact with children's level of inhibitory control, and consequently with age, since inhibitory control is known to vary with age (Lane & Pearson, 1982).

3.2.3. Methods

3.2.3.1. Participants

This experiment was run on an opportunistic sample of 47 primary school children tested at the University during a public engagement event called Bright Sparks. Children were invited to participate in pedagogical activities about the brain, as well as in research. Data from three children (two who were not fluent in English and one with a hearing impairment) were

excluded from the analyses. The final sample included 44 children, from 4.95 to 11.36 years of age. To facilitate comparisons with Experiment 1, the children were split into two age groups representing lower (UK Key stage 1) and upper (UK Key stage 2) primary school. The younger group included children from 4.95 to 8 years of age ($n = 23$, $M = 6.54$, $SD = .95$, 16 girls), whereas the older age group included children from 8.31 to 11.36 years of age ($n = 21$, $M = 9.65$, $SD = .91$, 7 girls). The project received ethical approval from both the Departmental and College Ethics Committees. Following an opt-in procedure, all the participants gave verbal consent to participate, and written informed consent was obtained from their guardian. The study was conducted in accordance with the Declaration of Helsinki.

3.2.3.2. Procedure

Children were tested individually over three short sessions, presented in Table 3.1. *Session A* included assessments of inhibitory control and of visuo-spatial working memory. *Session B* included a measure of verbal working memory. All tasks in *Session A* and *Session B* were performed in silence. In *Session C*, two idea generation tasks were performed (Alternative Uses Task and Just Suppose, see the Measures section below for details). Each of these tasks was performed twice in a row, once in silence and once in noise. Whether the Alternative Uses Task or Just Suppose was first was counterbalanced across participants. The order of the noise conditions was counterbalanced in a semi-random way, to ensure there were neither two consecutive tasks in silence, nor two consecutive tasks in noise. In other words, all children consistently had to switch between silence and noise when tested for creativity. See Appendix B for a complete table of the counterbalancing manipulation.

Table 3.1. Content of the testing sessions in Experiment 2

Session A	Session B	Session C
Inhibitory control (Flanker)	Verbal Working Memory	Idea generation tasks
Inhibitory control (Stroop)		(Alternative Uses Task, Just
Visuo-spatial Working Memory		Suppose)

The presentation order of the three testing sessions was randomised across children, and the children were given short breaks between each testing session. In total, testing took one hour. Parents were invited to fill in a socio-demographic questionnaire while their child was being tested. In particular, socio-economic status was assessed to make sure that the younger and older children of the sample had a comparable family background.

The noise stimulus was identical to the mixed noise used in Experiment 1, and consisted of classroom noise including bits of conversation, movement noise and outside noise. The verbal meaning of the conversations was difficult to perceive, since the different sources of noise were overlapping. The noise was played at 64.3dB(A) on average ($L_{Aeq(5min)} = 63.1dB(A)$; Range = [52.8-76.1dB(A)]) through external speakers. This average noise level was deliberately slightly below the 70dB level used in Mehta et al., (2012) to allow for the additional noise created by the experimenter and the participant, who were themselves talking and manipulating objects – the participant had to give their answers orally. The noise was played during the entire duration of the Alternative Uses Task (3 minutes) and of the Just Suppose Task (5 minutes). During the silent session, the participant was only exposed to the natural noise made by the experimenter who was writing down their answers. Since testing was

performed in an individual booth, children were not exposed to additional sources of external noise.

3.2.3.3. Measures

Socioeconomic status was measured by two indicators. First, parents reported their highest level of education (Hackman, Gallop, Evans, & Farah, 2015), coded on a 5-points Likert scale (1: High school; 2: Some college; 3: Undergraduate degree; 4: Some postgraduate; 5: Higher postgraduate). Second, postcodes were used to compute the Index of Multiple Deprivation corresponding to the family's home. This index ranks areas from 1 (most deprived) to 32,844 (least deprived) according to seven domains: income, employment, education, health, crime, barriers to housing and the living environment (Department for Communities and Local Government, 2015; <http://dclgapps.communities.gov.uk/imd/idmap.html>; see Barnes, Belsky, Broomfield, Melhuish, & the National Evaluation of Sure Start (NESS) Research Team, 2006 for the use of the IMD in educational research).

Working memory

Verbal working-memory was tested using a backwards digit span task (St Clair-Thompson & Gathercole, 2006). Children had to repeat back in reverse order a list of digits spoken by the experimenter. They were given a practice trial with two digits, and the experimenter clarified the instructions if the participant got it wrong. Following this practice, list length started at two digits and there were four trials per list-length level. Children had to succeed on three trials to move on to the next level. The total number of correct trials was

recorded. This task had the same logical structure than the computerised backward digit span task used in Experiment 1, but it relied on the auditory, instead of the visual modality.

Visuo-spatial working memory was assessed using a computerised variant of the Corsi block task (Berch, Krikorian, & Huha, 1998): the frog matrices task, programmed with Matlab 9.1.0. Participants saw a display of 9 lily pads (3x3, see Figure 3.2). They had to remember the movements of a frog, jumping on the lily pads, and to click on them in reversed order (also see Morales, Calvo, & Bialystok, 2013 for the same task design, but using a forward recall procedure). Children were given two practice trials with a list length of two. That is to say, the frog started from a given lily pad, and jumped twice. It stayed on the final lily pad and children had to click on the previous two lily pads, starting with the most recent. Following the practice, four more trials with a list-length of two were presented. Children had to succeed on three trials before moving on to the next level. The list-length then increased by one, and the procedure was carried out until children failed at more than one trial for a given list length. The total number of correct trials was recorded.

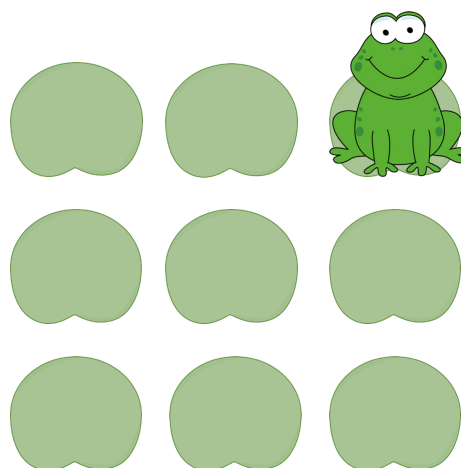


Figure 3.2. Stimulus for the visuo-spatial working memory task

Inhibitory control

A non-verbal Stroop task was programmed with Matlab 9.1.0 (Catale & Meulemans, 2009). Four pairs of animals were presented (lion and rabbit; horse and frog; mouse and elephant; cow and ladybird). For each pair, the picture of one animal was bigger than the other one. Participants had to indicate which was the bigger animal *in real life*, an answer which corresponded to the bigger picture in *congruent* trials and to the smaller picture in *incongruent* trials (see Figure 3.3). In other words, children had to inhibit the perceptual characteristics of the stimuli, in order to answer according to the animals' real relative size. Children answered by pressing the "X" or "M" buttons on the keyboard. These buttons were selected so that children could put one hand on each response key. Buttons were covered by arrows stickers (left arrow for "X"; right arrow for "M") to point at the animal children wanted to select. Participants were asked to answer as quickly and accurately as possible. If children took longer than 3000 ms to answer, the trial was terminated and the answer was counted as incorrect. The interstimulus interval lasted 500 ms. After the experimenter had introduced the task, there were 6 practice trials. Two blocks of 36 trials were then presented, 50% of the trials being congruent. Self-paced breaks were provided between the blocks. Accuracy (the proportion of correct trials) and Reaction Times for correct answers (RTs) were recorded.

Which is the biggest animal in real life?

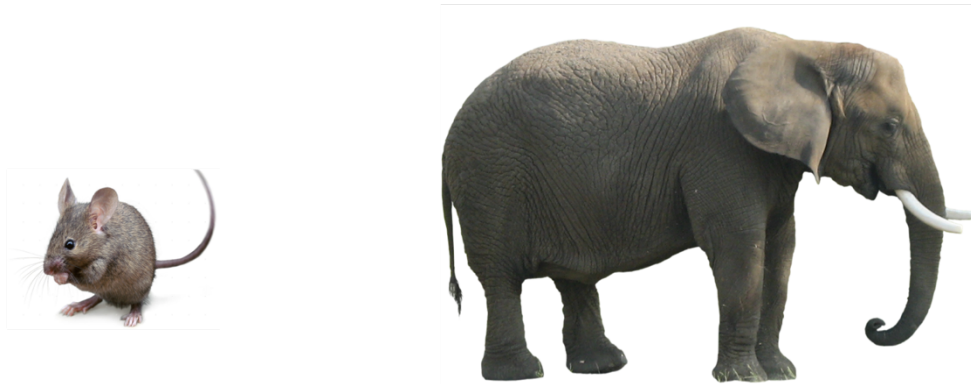


Figure 3.3. Example of a trial for the Stroop task

The same **Flanker task** as in Experiment 1 was used (Anwyl-Irvine, Massonnié, Flitton, Kirkham, & Evershed, 2019; adapted from Rueda et al., 2004). A horizontal row of five cartoon fish was presented in the centre of the screen, and participants had to indicate the direction the middle fish was pointing (either to the left, or right). In *congruent* trials, the middle fish was pointing in the same direction as the flanking fish. In the *incongruent* trials, the middle fish was pointing in the opposite direction. There were 96 test trials. Participants were asked to answer as quickly and accurately as possible. Accuracy (the proportion of correct trials) and Reaction Times for correct answers (RTs) were recorded. There was no timeout within the task. However, to ensure that reaction time limits would be equivalent to that of the Stroop task, trials for which children took longer than 3000ms to answer were excluded.

Idea generation

The Alternative Uses Task (AUT) was used to compare results with those reported in Mehta et al. (2012). Children had to come up with as many interesting and unusual uses as they could for two everyday objects - a plastic bottle and a pencil - within three minutes. They were asked to use their imagination to come up with new ideas and to go beyond the uses they had seen or heard before. The exact instructions are provided in Appendix C. The task was scored according to two dimensions: Fluency and Originality. Fluency scores correspond to the total number of ideas given by a participant; all answers were counted, except answers that were an exact repetition of the instruction - e.g. saying that a pencil could be used to draw or to write. Elaborations such as “drawing a flower”, “drawing a house” were counted, since they were not an exact repetition of the instructions. Finally, responses that were too broad to represent a specific idea (e.g: “you can use it to make things”) were also removed. Interrater reliability, calculated on 25% of the sample, was high ($\alpha = 1$ for both objects).

Originality scores were calculated for each idea that contributed to the fluency score (that is to say, repetitions were also excluded for originality scoring). As in Mehta et al. (2012), originality ratings for the AUT were made by four external raters, following a “Consensual Assessment Technique” (Amabile, 1982). Using a scale from 1 (not at all creative) to 5 (highly creative), raters were instructed to take into account their “sense of originality and inventiveness of each response, in one holistic measure”. Scores given by the four raters were averaged for each answer. This method broadly includes a rating of appropriateness in the concept of “inventiveness”. This dimension was not over-emphasised, however, because this would mean projecting adults’ judgements of utility on children’s ideas and some ideas can be meaningful to children in ways that differ from adults’ standards (Runco, 2003). Our

method reflects only one way to score the AUT. The frequency method is also widely used, but revealed several limitations when we tried to apply it. This method involves compiling a list of all the answers provided by the participants, and selecting a threshold below which ideas can be considered “unusual”. For example, an idea that is given less than 5% of the time could be given a point for originality, and an idea that is given less than 1% of the time 2 points. Using this method raised two major issues. First, compiling a list of ideas and selecting which ones were “unique” was difficult, given that every answer was worded slightly differently. Interrater agreement was hard to reach. Furthermore, choosing if two similar yet different ideas (e.g: “drawing a house” and “drawing a house invaded by zombies”) should be considered “unique” seemed to reflect a process of categorization that is more characteristic of flexibility processes (the capacity to give different categories of ideas), than of originality *per se*. Given the high level of interrater reliability that was achieved using the external raters method ($\alpha_{\text{pencil}} = .80$, $\alpha_{\text{bottle}} = .82$), this widely-used scoring procedure was deemed preferable.

The Just Suppose Task (JS) from Torrance (2016) was also used to evaluate the generalisability of the findings. Children were presented with two imaginary situations. In the first one (“Strings”), they had to “imagine [that] clouds had strings attached to them and [that] the strings hang all the way down to the ground”. In the second one (“Fog”), they were told to “imagine [that] a great fog was to fall over the Earth and [that] all we could see of people would be their feet”. After having heard each scenario, children were asked to suppose that the situation really happened, and were prompted to think about all the other things which might happen because of it, within 5 minutes. The task was scored according to two dimensions: Fluency and Originality.

Fluency, as for the AUT, represents the total number of ideas given by a participant. All answers were counted, except answers that were an exact repetition of the instruction. Interrater reliability, calculated on 25% of the sample, was high ($\alpha = .99$ for both scenarios).

Originality was scored following the method provided by Torrance (2016). Interrater agreement was high ($\alpha_{\text{strings}} = .89$, $\alpha_{\text{fog}} = .69$).

A self-report measure of noise distraction was included at the end of the noisy session. Children were asked whether they found the noise Not at all (1), A bit (2), or Very distracting (3). They were also invited to comment openly on their answer.

3.2.4. Results

3.2.4.1. Pre-processing of the Flanker and Stroop tasks

Accuracy was at ceiling for both the Flanker ($M_{\text{congruent}} = 95.28\%$; $M_{\text{incongruent}} = 92.15\%$) and the Stroop ($M_{\text{congruent}} = 95.02\%$; $M_{\text{incongruent}} = 92.34\%$) tasks. Therefore, reaction times for correct answers were retained as the main outcome of interest. RTs under 200ms (being too short to follow the perception of the stimuli), and above 3 standard deviations from the mean of each subject were excluded (Koivisto & Grassini, 2016; Rutiku et al., 2016; Whelan, 2008). A participant had a mean RT for incongruent trials, and a difference in RTs between congruent and incongruent trials that were 3.45 and 3.85 standard deviations away from the mean, respectively. To avoid this outlier from driving the results, their scores were removed from further analyses of the Flanker task. Descriptive statistics for the Stroop and Flanker tasks are reported in Table 3.2.

Table 3.2. Reaction times for congruent and incongruent trials at the Flanker and Stroop task, per age group

	Stroop		Flanker	
	<i>Congruent</i>	<i>Incongruent</i>	<i>Congruent</i>	<i>Incongruent</i>
Young	1064.90	1170.69	967.52	1007.16
Old	862.05	913.36	797.71	831.03
Full Sample	968.31	1048.15	884.69	921.25

An analysis of variance, with Congruency (Congruent trials vs Incongruent trials) as a within-subject factor, and Age as a between-subject factor, was carried out for each task.

For the Stroop task, RTs were significantly longer for incongruent than congruent trials ($F(1, 40) = 38.45, p < .001, \eta^2_p = .490$). There was a main effect of Age, showing that children above 8 years of age were generally faster ($F(1, 40) = 18.42, p < .001, \eta^2_p = .315$). The effect of Age interacted with that of Congruency, the difference between congruent and incongruent trials being smaller for the older group ($F(1, 40) = 4.62, p < .038, \eta^2_p = .104$).

For the Flanker task, RTs were also longer for incongruent than congruent trials ($F(1, 39) = 12.95, p = .001, \eta^2_p = .249$). As for the Stroop task, children above 8 years of age were globally faster than their younger peers, as indicated by a main effect of Age ($F(1, 39) = 10.96, p = .002, \eta^2_p = .219$). There was no interaction between Age and Congruency ($F(1, 39) = .10, p = .757, \eta^2_p = .002$).

Reaction time cost scores (RTs incongruent trials - RTs congruent trials) were used as the main measure of inhibitory control in further analyses. Higher values indicate poorer inhibitory control, since it takes longer to give the correct answer for incongruent trials compared to congruent trials.

3.2.4.2. Group differences

There was no significant difference in socio-economic status between the two age groups, as revealed by a Chi-Square test carried out on the parental education measure ($\chi^2(4) = 1.511, p = .825$), and by an independent sample T-test performed on the Index of Multiple Deprivation (IMD) ($t(35) = .34, p = .737$). Overall, parental education was relatively high: 47.7% of the parents had achieved a postgraduate level of education and 20.5% of them achieved an undergraduate level of education. Only 4.5% stopped at a college level, and 2.3% at a secondary school level of education. The median for the Index of Multiple Deprivation was 19 040, and ranged from 641 (indicating that some families came from the 10% most deprived areas of the UK), to 32 832 (10% least deprived areas). However, not all parents completed the questionnaire. Parental education and IMD data were only available for 33 (75%) and 37 (84%) children respectively.

Table 3.3 reports the means and standard deviations for each executive function measure per age group, as well as the results of independent sample T-tests comparing the two groups. Missing data for some tests are due to children's desire to stop, or programming errors (in the computerised visuo-spatial working memory task). For all the T-tests, the assumption of equality of variance between the two groups was tested with the Levene's Test. No violations

were identified, with all p -values above .281. Similarly, distributions were checked to verify the assumption of normality. Only the distributions for the Flanker task significantly departed from normality (for the younger group, Shapiro-Wilk $W = .859$, $p = .006$; for the older group, $W = .873$, $p = .013$). Results indicated that younger children had lower verbal and visuo-spatial working memory, and higher Congruency costs at the Stroop task, indicating lower inhibitory control.

Following reviewers' suggestions during the publication of this study, Bayes Factors in favour of the alternative hypothesis (noted BF_{10}) were also calculated. The alternative hypothesis states that there is a difference between the two age groups. Tests were double-sided to mimic the T-tests. Bayes factors quantify evidence in favour of the alternative hypothesis in a more continuous fashion than the p -value, and offer an alternative way to assess the strength of the effects, given the relatively small sample size of the study. The magnitude of the evidence is presented as an odds-ratio (Quintana & Williams, 2018). Indicative thresholds to measure the strength of the evidence range from 3 (moderate evidence) to 100 (very strong evidence). Numbers between 10 and 30 represent strong evidence. More information on Bayesian models and the corresponding procedures can be found in Quintana & Williams, 2018; Wagenmakers, Love, et al., 2018; Wagenmakers, Marsman, et al., 2018. Here, the Bayes Factor for the verbal working memory test indicates that the observed data is 19.95 more likely under the alternative hypotheses than the null. This could be considered as strong evidence for a difference between the two age groups. Similarly, the Bayes factor for the visuo-spatial working memory test brings confidence in the T-tests result, providing very strong evidence in favour of the alternative hypotheses. However, the age difference at the Stroop task, as assessed by the Bayes factor, can be considered inconclusive.

Table 3.3. Executive functions scores per age group

	Younger children			Older children			<i>Indep. Sample T-test</i>	<i>BF₁₀</i>
	<i>n</i>	<i>M</i>	<i>SD</i>	<i>n</i>	<i>M</i>	<i>SD</i>		
VWM	23	7.35	2.55	20	9.75	2.07	$t(41) = -3.35, p = .002$	19.95
VSWM	20	5.15	3.69	17	9.88	3.79	$t(35) = -3.84, p < .001$	55.69
Flanker	21	39.64	77.42	20	33.33	48.36	$t(39) = .31, p = .757$	0.32
Stroop	22	105.78	89.62	20	51.31	72.64	$t(40) = 2.15, p = .038$	1.83

VWM: Verbal Working Memory; VSWM: Visuo-spatial Working Memory; Scores for the Stroop and Flanker tasks represent the difference between reaction times for correct answers at incongruent and congruent trials (RT Incongruent – RT Congruent).

3.2.4.3. The impact of classroom noise on children's creativity

Next, the impact of noise on idea generation was assessed, along with its interaction with Age. A MANOVA was run for each of the four creativity scores (AUT Fluency and Originality, Just Suppose Fluency and Originality). The dependent variables (repeated measures) were the scores in silence and noise. The three counterbalancing factors and Age group were entered as independent, between-subject variables. Bayes factors were also computed. They were extracted from the analysis of effect of Bayesian Repeated Measures ANOVAs, using the same variables as the classical models. The default prior included in JASP 0.9.0.1 was used. Bayes factors not only offer the advantage of providing a more continuous representation of the evidence in favour of the alternative hypothesis, they also allow us to weight the evidence for the null hypothesis. In other words, they can be used to assess the evidence of an effect

(evidence for the alternative hypothesis, noted BF_{10}), and the evidence for the *absence* of an effect (evidence for the null hypothesis, noted BF_{01}).

Since the within-subject difference between creativity scores obtained in silence and noise was the focus of these analyses, for both types of analyses, data points for which this difference was three standard deviations from the mean were excluded from the analyses. This corresponded to a maximum of one child being excluded per creativity test. Descriptive statistics are reported in Tables 3.4 and 3.5.

Table 3.4. Scores at the AUT for the Younger and Older children, in silence and noise

	Younger Children				Older Children			
	Min	Max	<i>M</i>	<i>SD</i>	Min	Max	<i>M</i>	<i>SD</i>
Fluency								
Silence	2	21	9	4.84	3	17	8.29	3.65
Noise	1	19	8.91	4.98	4	20	7.95	4.24
Originality								
Silence	1.71	3.50	2.59	.52	1.42	3.78	2.92	.55
Noise	1	3.50	2.36	.66	2.02	4.25	2.97	.55

Alternative Uses Task

Fluency scores

There was no main effect of Noise on the fluency scores in the Alternative Uses Task ($F(1, 38) = .21, p = .651, \eta^2_p = .005$). The Bayes Factor indicates that the null hypothesis (of no difference between silent and noisy sessions) is 12.66 times more likely than the alternative hypothesis

stating that there is a difference. There was no main effect of Age on the fluency scores ($F(1, 38) = 1.37, p = .249, \eta^2_p = .035, BF_{01} = 2.80$). Finally, the effect of Noise did not interact with Age ($F(1, 38) = .02, p = .887, \eta^2_p = .001, BF_{01} = 12.20$).

Originality scores

For the originality scores, traditional MANOVAs indicated no main effect of Noise ($F(1, 38) = .94, p = .338, \eta^2_p = .024, BF_{01} = 4.48$). There was a main effect of Age ($F(1, 38) = 9.11, p = .005, \eta^2_p = .193$), showing that older children gave more original answers than their younger counterparts. This was supported by a Bayesian Factor indicating that the alternative hypothesis was 9.31 more likely than the null hypothesis. Although the effect of Noise significantly interacted with Age ($F(1, 38) = 5.05, p = .030, \eta^2_p = .117$), this was not strongly supported by Bayesian analyses ($BF_{10} = 1.38$). Follow-up repeated measures T-tests indicated that the difference in performance between silent and noisy sessions was neither significant for the younger children ($t(21) = 1.76, p = .092, BF_{01} = 1.20$), nor for the older ones ($t(20) = -.43, p = .672, BF_{01} = 4.04$).

Table 3.5. Scores at Just Suppose for the Younger and Older children, in silence and noise

	Younger Children				Older Children			
	Min	Max	<i>M</i>	<i>SD</i>	Min	Max	<i>M</i>	<i>SD</i>
Fluency								
Silence	1	23	9.82	5.67	3	20	11.33	4.54
Noise	2	19	8.23	4.77	2	20	11.19	5.09
Originality								
Silence	1	20	7.36	4.82	2	18	8.57	4.02
Noise	0	18	5.55	4.45	1	18	8.86	4.49

Just Suppose*Fluency scores*

There was no main effect of Noise ($F(1, 38) = 2.97, p = .093, \eta^2_p = .073, BF_{01} = 3.40$) and no main effect of Age ($F(1, 38) = 2.65, p = .112, \eta^2_p = .065, BF_{01} = 1.24$) on the fluency scores at the Just Suppose task. Furthermore, the interaction between Noise and Age was not significant ($F(1, 38) = 3.13, p = .085, \eta^2_p = .076, BF_{01} = 2.10$).

Originality scores

Regarding Originality scores at the Just Suppose test, there was no main effect of noise ($F(1, 38) = 2.67, p = .111, \eta^2_p = .066, BF_{01} = 1.40$). There was no main effect of Age ($F(1, 38) = 3.165, p = .083, \eta^2_p = .077, BF_{01} = 1.24$), but an interaction between the effect of Noise and of Age ($F(1, 38) = 4.97, p = .032, \eta^2_p = .116$). Younger children had lower originality scores in noise compared to silence ($t(21) = 2.24, p = .036, BF_{10} = 1.75$), whereas there was no significant difference between the conditions for older children ($t(20) = -.46, p = .653, BF_{01} = 4.00$). Note, however, that the interaction is not strongly supported by Bayesian analyses ($BF_{10} = 1.04$).

3.2.4.4. The modulating role of executive functions.

Developmental differences only provide indirect evidence for the role of executive functions in coping with noise (since executive functions tend to improve with age). Therefore, further analyses were carried out to investigate whether there were any two-way interactions between the effect of Noise and Executive functions, or three-way interactions between Noise, Executive functions and Age. For each of the four creativity measures (AUT Fluency and Originality, Just Suppose Fluency and Originality) the same variables as in the section 3.2.4.3. “The impact of classroom noise on children’s creativity” were entered into a

MANOVA, but Verbal working memory, Visual working memory, Stroop and Flanker performance were added as between-subject factors, in four successive models. For each executive function variable, a “low” and a “high” performance group was created, based on the median score of the entire sample for each test. Although executive functions were analysed in a continuous way in Chapter 2, given the presence of a dichotomous age variable in the present study, a median split for executive functions allowed to better understand and plot the effects by distinguishing four groups of participants: younger children with low executive functions, younger children with high executive functions, older children with low executive functions, older children with high executive functions.

There were no interactions between Noise and Executive Functions, nor any three-way interaction between Noise, Executive Functions and Age for the AUT Fluency and Originality scores. However, there were two significant interactions involving Originality scores in the Just Suppose task.

First, the impact of Noise on the Originality scores in the Just Suppose task interacted with inhibitory control as assessed by the Flanker task ($F(1, 33) = 12.86, p < .001, \eta^2_p = .280, BF_{10} = 5.57$). This interaction is depicted in Figure 3.4. Follow-up T-tests revealed that children with low inhibitory control gave ideas that were less original in noise ($M = 6.80$), compared to silence ($M = 8.80; t(19) = 2.67, p = .015, BF_{10} = 3.60$). In other words, children who were sensitive to incongruent distractors at the Flanker task ($M_{RT_{cost}} = 84.25\text{ms}$) were also impeded by noise when they performed the creative task. In contrast, there was no significant difference in performance between the silent ($M = 7.00$) and noisy ($M = 7.75$) sessions for

children with high inhibitory control skills ($t(19) = -1.097, p = .287, BF_{01} = 2.54$). Interestingly, these children were either more resistant to interference on incongruent trials in the Flanker task, or were faster at incongruent trials ($M_{RT\ cost} = -8.07ms$). In other words, the children who did not experience the expected Flanker interference also did not experience interference from noise.

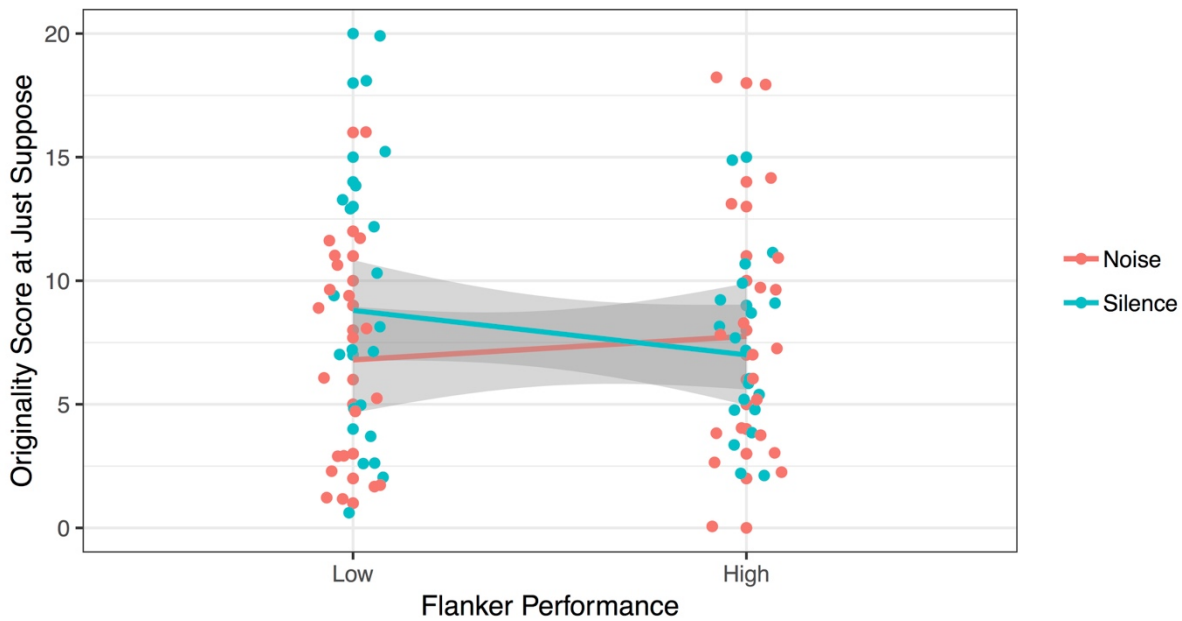


Figure 3.4. Originality of answers at the Just Suppose task, as a function of Flanker

Performance. The grey shading represents the 95% confidence interval around the estimate.

In addition to this two-way interaction, analyses revealed a three-way interaction between Noise, Age and the second measure of inhibitory control, the Stroop task ($F(1, 34) = 9.59, p = .004, \eta^2_p = .220, BF_{10} = 1.77$)⁵. Follow-up T-tests revealed that young children with low inhibitory control ($M_{RT\ cost} = 166.91ms$) gave more original answers in silence ($M = 7.58$) compared to noise ($M = 4.25; t(11) = 4.318, p = .001, BF_{10} = 33.89$). This effect was very strong.

⁵ The three-way interaction between Noise, Age and Flanker performance was not significant ($F(1, 33) = .00, p = .986, \eta^2_p = .00$).

In contrast, there was no significant difference in originality scores between the noisy and silent sessions for the young children with high inhibitory control ($M_{RT\text{ cost}} = 25.39\text{ms}$; $M_{\text{Silence}} = 7.78$; $M_{\text{Noise}} = 7.56$; $t(8) = .149$, $p = .885$, $BF_{01} = 3.08$) and for the older children with low inhibitory control ($M_{RT\text{ cost}} = 122.41\text{ms}$; $M_{\text{Silence}} = 8.13$; $M_{\text{Noise}} = 9.88$; $t(7) = -2.084$, $p = .076$, $BF_{01} = 0.72$) and high inhibitory control ($M_{RT\text{ cost}} = 4.08\text{ms}$; $M_{\text{Silence}} = 8.67$; $M_{\text{Noise}} = 7.92$; $t(11) = .888$, $p = .394$, $BF_{01} = 2.50$). These results are represented in Figures 3.5 and 3.6.

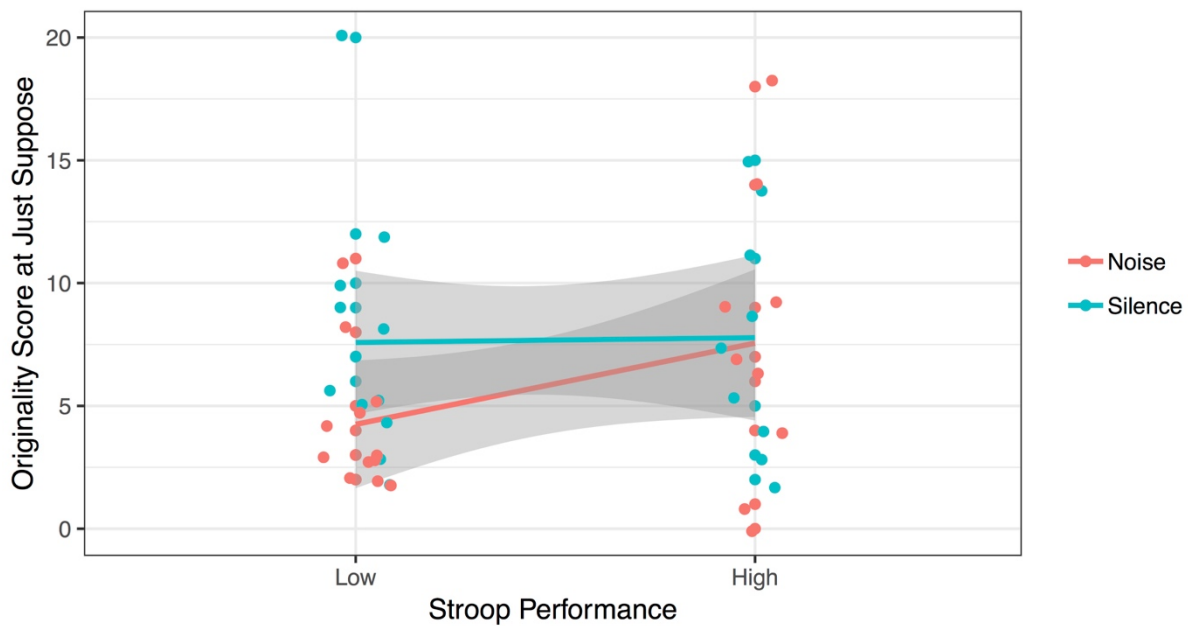


Figure 3.5. Originality of answers at the Just Suppose task, as a function of Stroop

Performance, for the Young group. The grey shading represents the 95% confidence interval around the estimate.

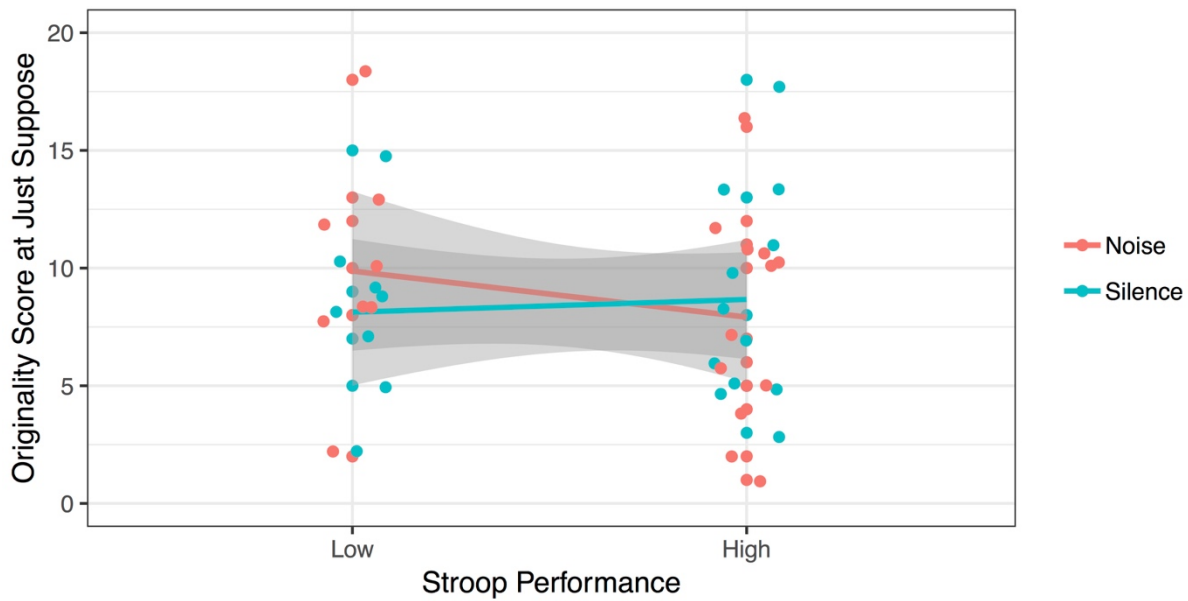


Figure 3.6. Originality of answers at the Just Suppose task, as a function of Stroop

Performance, for the Old group. The grey shading represents the 95% confidence interval around the estimate.

A similar three-way interaction between Noise, Age and Stroop performance emerged for Fluency scores at the Just Suppose task ($F(1, 34) = 4.35, p = .045, \eta^2_p = .113, BF_{10} = 0.38$)⁶. Follow-up T-tests parallel the previous results on originality scores. Young children with low inhibitory control gave more ideas in silence ($M = 9.67$) compared to noise ($M = 7.08; t(11) = 2.416, p = .034, BF_{10} = 2.22$). On the contrary, there was no significant difference in fluency scores between the noisy and silent sessions for the young children with high inhibitory control ($M_{\text{Silence}} = 11; M_{\text{Noise}} = 10; t(8) = .832, p = .430, BF_{01} = 2.34$) and for the older children with low ($M_{\text{Silence}} = 10.50; M_{\text{Noise}} = 12; t(7) = -1.620, p = .149, BF_{01} = 1.16$) and high ($M_{\text{Silence}} = 11.17; M_{\text{Noise}} = 10.33; t(11) = 1.034, p = .323, BF_{01} = 2.23$) inhibitory control.

⁶ The three-way interaction between Noise, Age and Flanker performance was not significant ($F(1, 33) = .01, p = .923, \eta^2_p < .001$).

3.2.4.5. Relation between the impact of noise on performance and children's subjective perception of being distracted

Did the inter-individual variability in the effect of noise matched children's subjective perception of being distracted? For each idea generation task, a difference score (Performance in Silence – Performance in Noise) was computed. Kruskal-Wallis Tests showed that these difference scores were not related to children's self-report of distraction (for AUT Fluency: $\chi^2(2) = 2.74, p = .254$; AUT Originality: $\chi^2(2) = .01, p = .994$; JS Fluency: $\chi^2(2) = 2.85, p = .241$; JS Originality: $\chi^2(2) = .90, p = .637$).

Of special interest here is to assess whether children's self-report of distraction was related to their level of executive functions. Indeed, Mehta et al. (2012) suggested that noise could enhance creativity by inducing an optimum amount of distraction, but it was measured through self-report. It is important to assess whether the self-report measure used in Experiment 2 matched the executive function processes highlighted in other strands of the noise literature (see Chapter 2 and Sörqvist, 2010b; Sörqvist, Halin, & Hygge, 2010; Sörqvist, Ljungberg, & Ljung, 2010). Kruskal-Wallis Tests showed that it was not the case (for Verbal working memory: $\chi^2(2) = 1.90, p = .388$; Visuo-spatial working memory: $\chi^2(2) = 2.49, p = .288$; Stroop $\chi^2(2) = .64, p = .726$; Flanker $\chi^2(2) = .50, p = .780$)

3.2.5. Discussion

To our knowledge, this is the first developmental study assessing the impact of classroom noise on children's creativity. Two age groups, corresponding to early primary school (5 to 8 years of age) and late primary school (8 to 11 years of age) performed two idea generation tasks in silence and in noise.

It was assumed that older children would have better attentional and working memory skills, which could underlie age effects when evaluating the impact of noise on performance (Elliott, 2002). Comparisons between age groups showed that this difference was more striking for the working memory measures than for the tasks assessing inhibitory control (Flanker and Stroop tasks). In the Flanker task, the younger children did not show a larger difference between congruent and incongruent trials than the older children. This is consistent with Rueda et al. (2004) who found no effect of age on reaction times using a similar task with 6- to 9-year-olds. With regards to the Stroop task, analyses revealed that interference effects were greater for younger children. However, Bayesian analyses did not provide strong evidence for this difference. Results from Catale and Meulemans (2009), who used a similar Stroop task, indicate that the presence of a significant age effect might depend on the specific way age groups are created and compared, and might require stronger statistical power. On the contrary, age differences in the two working memory tasks were both supported by traditional T-test analyses and by Bayes Factors, giving strong evidence for the alternative hypothesis. Given that different components of executive functions demonstrate different

developmental trajectories (Anderson, 2002), these contrasting results are not completely at odd with the literature.

Groups differences for the creativity scores showed that older children gave ideas that were rated as more original on the AUT. This effect was supported by strong evidence from Bayes Factors. Working memory, general knowledge and intelligence are thought to play a role in the generation of original ideas (Beaty & Silvia, 2012; Benedek et al., 2014; Kleibeuker et al., 2016; Nusbaum & Silvia, 2011; Sternberg, 2006; Sternberg & O'Hara, 1999). Therefore, older children, whose skills are more developed, might be able to give more original ideas.

In line with Mehta et al. (2012), noise was expected to specifically and positively impact originality scores, an effect that could interact with children's age (i.e. noise might be too overwhelming for children in early primary school). Results revealed that the effect of noise on originality scores on the AUT and Just Suppose tasks significantly interacted with age. Follow-up tests indicated that older children performed similarly in both conditions, in both tests. The younger children gave fewer original ideas in noise than in silence for the Just Suppose task, but performed similarly in both conditions on the AUT. To sum up, it can be concluded that, contrary to expectations, older children did not benefit from noise when performing an idea generation task.

A direct assessment of working memory and inhibitory control made it possible to test whether these executive functions modulated the impact of noise on creativity. Similarly to Sörqvist, Halin, et al. (2010)'s results with adults, inhibitory control, but not working memory,

did interact with the effects of noise. Children who experienced more interference in the Flanker task (i.e. those with poorer inhibitory control) gave fewer original ideas in noise than in silence in the Just Suppose task. For those who experienced less interference in the Flanker task (i.e. those with better inhibitory control) there was no significant difference between silence and noise. In other words, the ability to resist interference from visual distractors went along with being less impeded by noise when generating new ideas.

Furthermore, a three-way interaction between the effect of Noise, Stroop performance, and Age emerged in predicting originality scores in the Just Suppose task. Children who did not show interference in the Stroop task appeared also to be immune to the effects of noise. Children who did experience Stroop interference were differentially affected according to their age. The younger children performed better in silence, whereas the older children performed similarly in the two conditions. Children in their early primary school years, with low inhibitory control skills, are therefore especially sensitive to the effect of noise when performing an idea generation task. This was strongly supported by Bayesian analyses. Note that follow-up analyses on older pupils were not as strongly supported by Bayesian factors. However, contrary to what was expected, older children (in their late primary school years), did not perform significantly better in the presence of moderate background noise, whatever their level of inhibitory control.

This three-way interaction suggests that inter-individual differences in inhibitory control when working in noise are particularly important in the early primary school years. In Chapter 2, focused on children in their late primary school years, inhibitory control did not modulate

the effect of noise on school performance. Overall, the Flanker effect was smaller in Experiment 1 ($M = 25.38$; $Min = -162.77$; $Max = 278.96$) than in Experiment 2 ($M = 36.56$; $Min = -49.92$; $Max = 273.75$). Anderson (2002) suggests that the inhibitory control of attention mostly develops before 8 years of age, and it is therefore possible that there were more interindividual differences within the younger group, than across the two age groups. The main limitation of Experiment 2 was its small sample size, resulting in age groups that were pretty broad. A higher number of participants (e.g. 20 to 30 children per school year) would allow for a more fine-grained understanding of developmental effects.

The fact that working memory did not modulate the impact of noise in the present study further support the idea that such modulation might only happen when the working memory task share common processes with the task performed in noise. Indeed in Experiment 1, working memory was modulating the effect of noise on a mathematics task (which also included the storage and manipulation of digits), but not on measures of reading comprehension and text recall.

3.3. Conclusion and future directions

To sum up, this is the first study attempting to assess the impact of moderate classroom noise on children's ability to generate new ideas, and its modulation by executive functions. Analyses revealed that young children with low inhibitory control might be especially vulnerable to the effect of noise: they gave fewer ideas in the presence of noise, and these

ideas were rated as less original. This has practical relevance given that noise levels in classrooms are actually louder in the early years (Picard & Bradley, 2001).

More work remains to be done to better understand the attentional processes involved when working in noise. Authors positing a role of attentional resources when dealing with noise have either based their claim on participants' performance at executive function tasks (Sörqvist, 2010b; Sörqvist, Halin, et al., 2010; Sörqvist, Ljungberg, et al., 2010), or on self-report measures of distraction (Mehta et al., 2012). In the present study, the extent to which children felt distracted did not relate to their performance at four executive functions task, assessing inhibitory control, verbal and visuo-spatial working memory. It is therefore possible that the two types of measures reflect different processes. The self-report measure, however, was only based on one question ("How distracting did you find the noise coming from the speaker?") with three possibilities of answer ("Not at all" / "A bit" / "Really" distracting). This measure was chosen to be easily understandable by the younger children of the sample, for which the use of continuous scales might have been difficult. A more comprehensive assessment of children's subjective reactions to noise is needed. This will be addressed in Chapter 4.

Chapter 4 - Children's reactions to noise in classroom settings: A
school survey

4.1. Chapter overview

To better understand children’s reactions to noise in naturalistic settings, this Chapter will present the results of a school survey targeting 8- to 11-year-olds. Results from Chapters 2 and 3 indicated that pupils’ subjective feeling of being distracted by noise when engaged in various tasks (text recall, text comprehension, mathematics, idea generation) hardly matched with the “objective” impact that noise had on their performance. This finding fits with previous studies investigating children’s annoyance (Slater, 1968) and sense of effort when working in noise (Hygge, 2003).

However, the investigation of children’s subjective reactions to noise in Chapters 2 and 3 relied on a single question (“How distracting did you find the noise coming from the headphones / speaker?”), with only three possible answers (“Not at all” / “A bit” / “Really distracting”). This is far from representing the broad range of reactions that children can have towards noise, let alone towards noise occurring in their classroom. The school survey presented in this chapter includes a wider assessment, based on the literature about noise annoyance and noise distraction. Children’s mind-wandering capacities and switching skills, which are assumed to rely on working memory and inhibitory control, will be investigated as potential mechanisms for coping with noise.

The approach used in this Chapter is shown in Figure 4.1. It focused on self-report measures of children’s reactions to noise, mind-wandering and switching skills. Since these questionnaires inquire about children’s reactions in everyday life, they have been classified as 1st person, classroom-related measures.

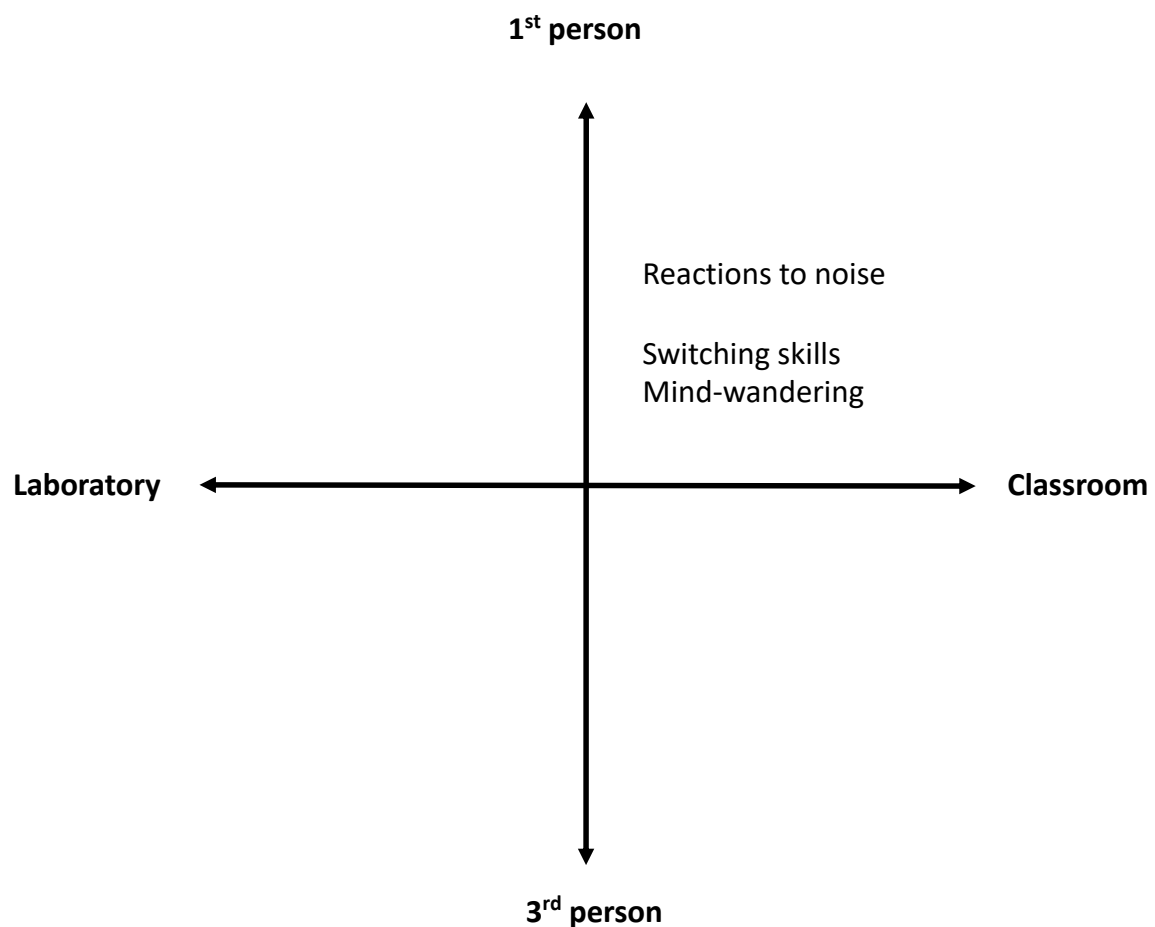


Figure 4.1. Methodological approach used in Chapter 4

4.2. Experiment 3: Assessing children's reactions to noise in classroom settings

4.2.1. Introduction

Community studies have raised awareness of children's perception of noise. They have shown that children living near airports are more annoyed by noise than those living in quieter neighbourhoods (Evans, Hygge, & Bullinger, 1995; Haines & Stansfeld, 2000; Haines, Stansfeld, Job, Berglund, & Head, 2001). Non-linear relationships have been reported, with annoyance levels particularly increasing for children exposed to more than 70dB of aircraft noise (Stansfeld et al., 2005) or railway noise (Lercher, Brauchle, Kofler, Widmann, & Meis, 2000). With regards to road traffic noise, Lercher et al. (2000) and Stansfeld et al. (2005) reported a linear and positive relationship between children's exposure to noise and ratings of annoyance.

However, there is a lot of variability in children's responses. Not all children report being annoyed. In Haines and Stansfeld (2000)'s study, 79% of the children living near Heathrow airport reported being only a little bit, or not at all annoyed by noise. This is lower than the 98% of the control group, but still non-negligible. These findings nuance interpretations of a direct relationship between noise exposure and annoyance, by showing that some children who are exposed to a lot of environmental noise do not report being very annoyed by it. The opposite is also true, with some children living in relatively quiet neighbourhoods reporting high levels of annoyance towards noise.

Studies about transportation noise are only partly helpful for understanding the impact of classroom noise on children's well-being. Indeed, aircraft and traffic noise have specific acoustic characteristics (intermittent, loud and low frequency noise) that are different from the mix of babble and environmental noise children are exposed to in their classroom. Studies about transportation noise might not represent the reality of schools which are only moderately exposed to these types of noise, and for which children's activities cover noise from outside (Shield & Dockrell, 2004). Several surveys have shown that the most annoying sources of noise reported by pupils and teachers are classroom chatter, and noise generated from movement (i.e. sounds from the corridor, scrapping chairs and tables; Boman & Enmarker, 2004; Enmarker & Boman, 2004; Lundquist, Holmberg & Landstrom, 2000). Again, if ratings of annoyance were, on average, moderate, substantial inter-individual variability was reported. Understanding the mechanisms behind this inter-individual variability might help to better identify which children are the most likely to suffer from noise and why, with the potential to develop solutions to alleviate their difficulties.

As pointed out by Guski (1999), to help reduce annoyance, it might be necessary to identify the attitudes and cognitive mechanisms underlying people's reactions when confronted with a specific noise source, in a specific situation. Theoretical accounts highlight the role of judgements and attitudes towards the source of noise (Guski, 1999; Stallen, 1999). For example, perceiving other people's conversations as a social signal instead of an intrusion into one's privacy can be related to less annoyance towards that source of noise (for an adult study, see Weinstein, 1978). Regarding transportation noise, the tendency to be afraid of aircrafts, and to judge them as unsafe can be associated with more annoyance towards aircraft noise. However, Haines and Stansfeld (2000) reported that these factors were not the

most determinantal for children exposed to aircraft noise in their classroom. Instead, annoyance was related to the fact that planes made it hard to think, or to work, that is to say, when there was an interference between noise, and children’s thoughts or activities.

This explanation has the advantage of also applying to the multitude of noise sources children are exposed to in their classroom: it is not specific to noise coming from conversations, from road traffic, devices or aircrafts. It fits with Boman and Enmarker (2004)’s interpretation that “annoyance arises in a situation in which the sound and the person’s intended activities are incompatible” (p. 208). In the classroom, children are engaged in learning activities most of the time. They report that noise is most annoying when they are doing an exam or a test, that is to say, when they are highly engaged in their work (Connolly, Dockrell, Shield, Conetta, & Cox, 2013). Several words, such as disturbance (Stallen, 1999), or distraction (Boman & Enmarker, 2004; Kjellberg et al., 1996) have been used in the literature to describe this process, although the term “interference” will be used here to be consistent across studies. It is not clear from previous research whether interference and annoyance are overlapping constructs, or whether they might be dissociated and underlined by different cognitive mechanisms.

Analysing the factorial structure of a questionnaire completed by 13- to 14-year-olds, Boman and Enmarker (2004) extracted a single factor, comprising items related to interference (e.g. noise making it difficult to concentrate) and annoyance/irritation (See Figure 4.2.a.). However, Stallen (1999) highlights the importance of dissociating these constructs (see Figure 4.3.b.). Interference, or the difficulty of achieving goals when noise taxes resources that are less available for the main task, has more to do with cognitive mechanisms describing the

interaction between a person and its environment. It does not contain an emotional reaction in itself. Annoyance, however, happens when the situation is disliked, or unwanted. In other words, depending on people’s judgement and capacity to cope with interference, they might be more or less annoyed by it. Coping strategies can be direct (e.g. directly acting on the noise, by reducing it, or negotiating with people responsible for noise) or indirect, via cognitive mechanisms such as cognitive control (Guski, 1999). In line with this idea, Kjellberg et al. (1996), extracted two factors from an adult survey on noise at work: one related to interference, one to annoyance. The Interference factor reflected the effects of noise on the work task, and difficulties to concentrate. The Annoyance factor was related to the number of actions taken against the noise, and to the tendency to often pay attention to the noise.

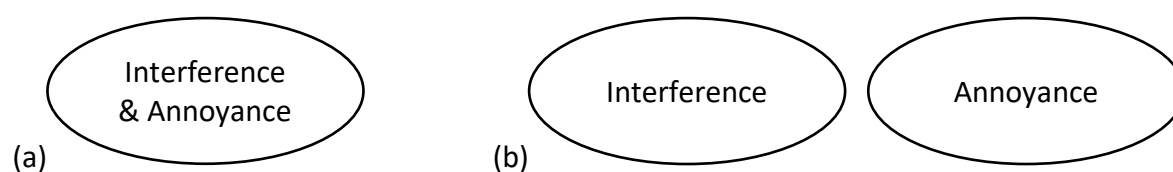


Figure 4.2. Two theoretical and empirical accounts of the relationship between noise interference and annoyance as (a) a single, or (b) two different construct(s)

On the one hand, some children can experience both interference and annoyance from noise. This seems to be the case for children with clinical hearing impairment, who have been identified as especially vulnerable, due to their greater difficulty in understanding speech embedded in noise (Connolly et al., 2013; Picard & Bradley, 2001; Shield, Greenland, & Dockrell, 2010; Shield & Dockrell, 2003). This can interfere with learning when the teacher is explaining concepts, or during group work, when children communicate while being surrounded with high levels of background noise (Shield & Dockrell, 2004). In Boman and Enmarker (2004) and Enmarker and Boman (2004), difficulties with hearing were assessed in a sub-clinical and continuous way, by asking middle school children how good their hearing

was, or to what extent they could hear when several persons were talking at the same time. Difficulties with hearing were again associated with more annoyance towards classroom noise, highlighting the need to take into account inter-individual variability in the general population. Pupils who find it hard to hear in the classroom context might have difficulties with adapting to sounds, or developing strategies, such as trying to concentrate more on the learning goal (since this goal in itself is not properly understood). Figure 4.3.a. illustrates the fact that difficulties with hearing predicts both interference and annoyance. Whether hearing status predicts annoyance *through* interference (Figure 4.3.b.) has yet to be tested, since Kjellberg et al. (1996) did not test this indirect effect, and since Boman and Enmarker (2004) and Enmarker and Boman (2004) did not differentiate interference and annoyance. A single model, including both direct and indirect effects, could be tested (see Figure 4.3.c.)

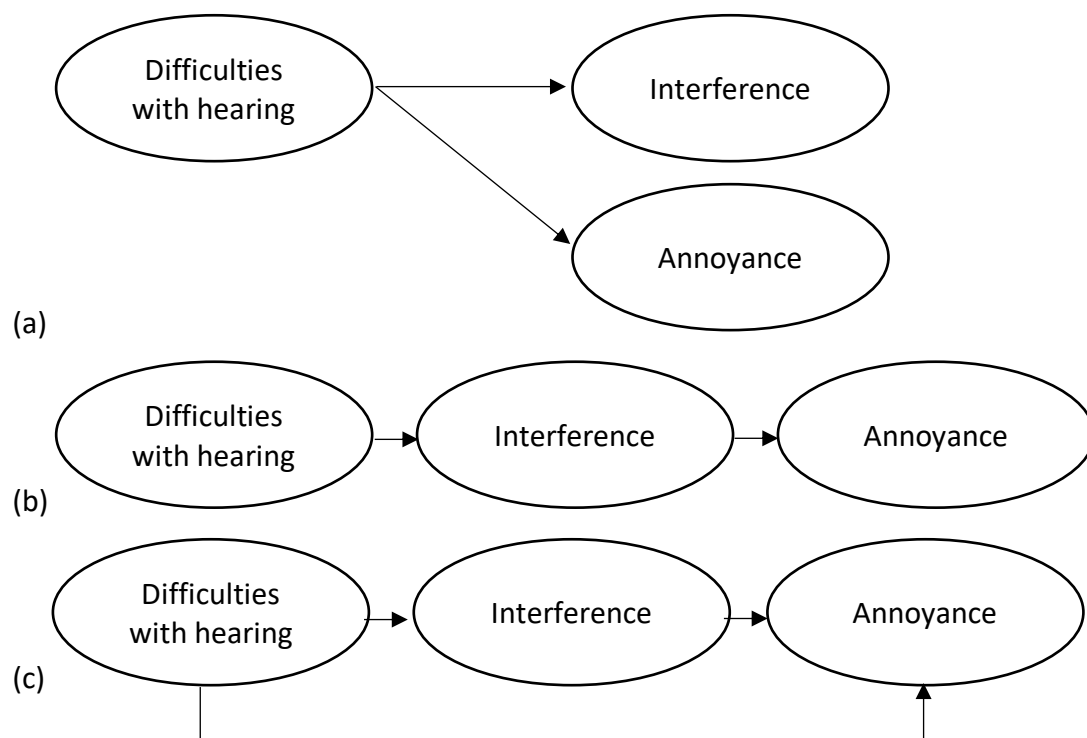


Figure 4.3. Difficulties with hearing can predict interference and annoyance from noise, as (a) two separate pathways, or (b) they can predict annoyance through interference. Model (c) combines both direct and indirect effects.

Some children, on the other hand, might experience interference, but not annoyance from noise. This might be the case for pupils who have a greater propensity for letting their minds wander. Mind-wandering happens when people are focused on things that are not related to their current task or to what is going on around them (Kam, 2017; Mrazek, Phillips, Franklin, Broadway, & Schooler, 2013). Instead, attention is shifted to inward processes, such as personal thoughts and feelings. In the classroom context, pupils' attention would be redirected away from the learning task (e.g. listening to the teacher or being engaged in homework), to focus on internal states of mind.

It might seem, at first, that such inward focus would reduce awareness of ambient noise. Indeed, according to Smallwood, Fishman, and Schooler (2007), mind wandering is accompanied by a reduced processing of sensory information, since the cognitive resources used for mind-wandering are less available to encode information from the environment. However, as pointed out by Kam (2017), it all depends on the kind of external events that are occurring, and mind-wanderers can still be sensitive to unexpected, surprising, or potentially dangerous stimuli. Since classroom noise contains a mix of diverse and irregular sounds (e.g. chatter, bells ringing, sounds coming from movement) it is possible that these sounds are detected even by pupils who tend to let their minds wander.

Furthermore, and contrary to Smallwood's theory that mind-wandering is demanding in terms of executive resources, some authors consider it a default mode, which needs to be regulated when one wants to focus on specific goals and tasks (McVay & Kane, 2010). In other words, people who often let their mind wander would have more difficulties with controlling their thoughts. According to this account, if mind-wanderers notice irregular

noise, and if they have difficulties focussing on their learning task to start with, they would be *particularly* vulnerable to noise interference. Laboratory studies on adults give weight to this hypothesis. Forster and Lavie (2014) have shown that a greater propensity for mind-wandering was associated with more distraction from task-irrelevant visual distractors. Using two self-report questionnaires, Carriere, Seli, and Smilek (2013) reported a positive correlation between mind-wandering and the tendency to experience interference from noise when engaged in tasks such as reading or working. To our knowledge, there have been no studies replicating this finding with children.

Of special interest to the discussion about the dissociation between interference and annoyance, mind-wanderers might not necessarily be annoyed by noise. When they experience interference, instead of focusing on the noise and getting annoyed by it, they could “escape” by primarily engaging with their own thoughts. In both situations, attention is decoupled, but mind-wandering would help to focus on positive feelings and thoughts, instead of focusing on unwanted sound. As such, Boman and Enmarker (2004) suggest that mind-wandering can help pupils handling noise (see Smallwood & Andrews-Hanna, 2013; for a fuller discussion of the costs and benefits of mind-wandering, taking into account both the situational context and the content of self-generated thoughts).

Studying inter-individual differences in pupils’ propensity to let their mind wander, along with their subjective report of noise interference and annoyance has both practical and theoretical interest. On the practical side, and given the prevalence of mind-wandering in the classroom (Szpunar, Moulton, & Schacter, 2013), teachers might want to understand whether those pupils who do not seem to pay attention to a lesson (because they are engaged in their own

thoughts) are relatively immune, or on the contrary particularly vulnerable to noise. On the theoretical side, testing whether mind-wanderers experience interference from noise, yet are not necessarily annoyed by it, would provide a more stringent test of the hypothesis that these two constructs are connected, yet partly dissociated. It would also give some insight into the processes at play, since mind-wandering has been associated with a failure of executive functions (McVay & Kane, 2010). Testing the model depicted in Figure 4.4. would help shed light on these questions. It was hypothesised that mind-wandering would predict interference from noise, but will not be directly related to annoyance. The extent to which mind-wandering predict annoyance *through* interference (indirect effect) remains to be tested.

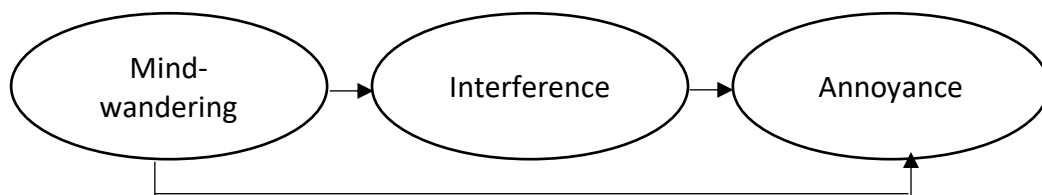


Figure 4.4. A model of mind-wandering as a predictor of noise interference and annoyance, combining both direct and indirect pathways

Avoiding noise annoyance by “escaping” into mind-wandering might help improve well-being, but it might not be efficient for fulfilling learning goals. Boman and Enmarker (2004) suggested another coping strategy, which is to try to concentrate more on the learning task. In other words, children might choose to devote their attention and cognitive resources to their ongoing activity, even if they experience interference from noise. How might this be possible?

If interference is conceived as a relative incompatibility between the perceived noise (e.g. a conversation), and the ongoing task (e.g. listening to the teacher, doing homework, Boman & Enmarker, 2004; Stallen, 1999), then the capacity to switch between one and the other might be of crucial importance. Switching is the capacity to appropriately alternate between two different tasks, or to refocus one’s attention back on an activity after having been interrupted. It relies on the capacity to inhibit unwanted representations (here, information coming from the noise), but also on the capacity to “load” representations for the task of interest (here, the learning task; Diamond, 2013). In other words, switching relies on both inhibitory control and working memory.

Laboratory studies have shown that children as young as 8 years of age are able to select, from multiple auditory channels, which channel they want to pay attention to, and to switch their attention based on instructions. These skills are developing throughout the primary school years (Doyle, 1973; Geffen & Sexton, 1978; Pearson & Lane, 1991). However, it is unclear how these findings would translate to real life situations, where children are exposed to multisensory (visual and auditory) distractors, while being engaged in complex learning activities. Carriere, Seli, and Smilek (2013)’s study on adults suggests that having good switching skills is related to lower interference from noise. The authors used questionnaires to assess participants’ switching capacities and the impact of noise on their concentration in various everyday life settings. Replication on children is needed, but switching skills might help them to get “back on track” and fulfil their goal despite the presence of distraction. In other words, switching skills would help them to cope with noise interference. However, it remains unclear how switching skills relate to annoyance. If noise interference is one of the main determinants of children’s annoyance in school settings, then switching would predict

annoyance *through* interference. Testing a model containing both direct and indirect effects, as in Figure 4.5., might help understanding these relationships.

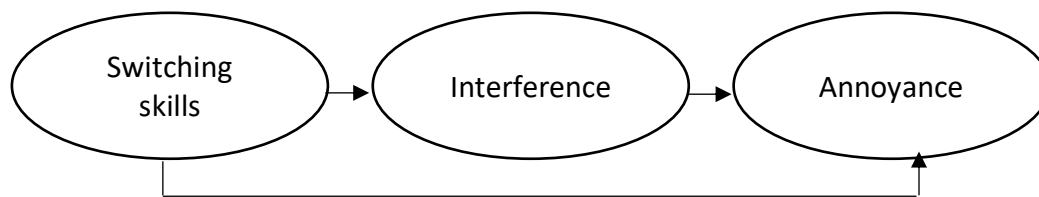


Figure 4.5. A model of switching skills as a predictor of noise interference and annoyance, combining both direct and indirect pathways

4.2.2. Aims of the current investigation

The present study is aimed at better understanding the relationships between the concepts of noise interference and annoyance. Following Kjellberg et al. (1996) and Stallen (1999), it was assumed that these two phenomena would be independent, yet correlated constructs. Their dissociation might allow a better understanding of the cognitive mechanisms behind children’s reactions to noise, and to identify different profiles of children who are more or less vulnerable to noise.

Replicating findings from the existing literature, it was predicted that children with difficulties hearing would experience more interference from noise, and would be more annoyed by it. Children with good switching skills were expected to be globally protected, experiencing less interference and less annoyance. To test the dissociation between noise interference and annoyance, it was assumed that children who have a greater propensity for mind-wandering would experience more interference from noise, yet would not be necessarily annoyed by it.

To address these questions, and following Boman and Enmarker (2004), factorial analyses were combined with regression analyses in Structural Equation Models.

4.2.3. Methods

4.2.3.1. Participants

Neurotypical children between the ages of 8 and 11 years were recruited from six French primary classrooms in Corsica (equivalent of Year 5 and Year 6 in the UK). This age range was selected to make sure children would have sufficient reading skills to answer the survey as part of a group testing session. One classroom contained some children in Year 4, and parental consent was obtained for 121 pupils (eight Year 4s, fifty-two Year 5s and sixty-one Year 6s). Year 4 students were excluded from the present analyses for the purpose of homogeneity. Data for one child, for whom hearing disorders were reported by the parents, were also removed from the analyses. The final sample includes 112 pupils, from 8.70 to 11.38 years of age ($M = 10.03$; $SD = .60$). The project received ethical approval from the University’s Departmental Ethics Committee. Following an opt-in procedure, all the participants gave verbal consent to participate, and written informed consent was obtained from their guardian. The study was conducted in accordance with the Declaration of Helsinki. The six participating classrooms were under the jurisdiction of a French educational inspector who approved the ethical guidelines of the study.

The six participating classrooms were situated in urban and suburban areas. Average noise levels in empty rooms, computed over 200 samples of 1 min recordings on the evening and night (World Health Organization, 2018), were at 30-40dB (depending on the classroom). The

minimal and maximal values recorded within the 200 samples were respectively of 29 and 45dB, indicating that the classrooms were not exposed to loud sources of external noise (such as aircraft or railway noise). Noise levels in occupied classrooms (with children engaged in their daily activities) were at 46-54dB on average (depending on the classroom), with a minimum of 34 dB and a maximum of 73dB (see Picard & Bradley, 2001, for a comparison - in the present study, sound level meters were placed on the front wall of the classrooms, to avoid the visible intervention of an experimenter, which can explain slightly lower values compared to some other studies).

4.2.3.2. Procedure

Self-report has been used as the main method to allow for comparison with previous studies assessing children’s reactions to noise in classroom settings (Boman & Enmarker, 2004; Connolly et al., 2013; Enmarker & Boman, 2004). All measures were part of a larger school survey, in Appendix D, and available to any interested researcher at https://drive.google.com/drive/folders/10_Kv9d-uO07ww_Mxum5YaLbSCqdC2vrN. To counterbalance the presentation order of the different questions, half of the children were given version A, and half of the children version B. Pupils answered the survey in their usual classroom, in a collective session and under the supervision of their teacher. They were left with enough time to answer all questions, could ask to clarify the meaning of some words if necessary, and were invited to leave a question blank if they really did not know what to answer. Children were invited to respond based on how they felt within the past two weeks. This was done to make sure that the measures would represent a variety of classroom

situations, and to avoid children from focusing on specific events (e.g. noise levels in the classroom when they filled the questionnaire).

4.2.3.3. Measures

Children’s reactions to noise

Five dimensions, related to children’s perception of, and reactions to noise, were defined *a priori*. They reflect: 1) the overall perception of noise levels in the classroom, 2) reported hearing difficulties, 3) attentional capture from noise (i.e. the fact that children notice noise), 4) interference from noise (i.e. the fact that noise catches children’s attention *and* interferes with their ongoing task), 5) noise annoyance. The last three sets of questions (attentional capture, interference, and annoyance related to noise), referred to various classroom situations, namely: 1) when the teacher, or a classmate talks to the entire classroom, 2) when the teacher, or a classmate comes closer to talk to the child, 3) individual work, 4) group work. This was done in order to reflect the broad range of learning activities children engage in. It seemed important to focus not only on speech comprehension problems, but also on individual work and group work which are regular learning activities. The exact wording of the questions and the response scales are in Table 4.1.

Switching skills and mind-wandering

The survey also included two sets of questions, measuring children’s switching skills and mind-wandering propensities. The questionnaire for switching skills was adapted from Carriere, Seli, & Smilek (2013)’s Attentional Control Switching scale. Scoring was reversed so that higher scores indicate better switching skills. The mind-wandering questionnaire was

borrowed from Mrazek, Phillips, Franklin, Broadway, & Schooler (2013). Higher scores correspond to a greater propensity for mind-wandering. The original items of both the switching and mind-wandering questionnaires are in Table 4.1. For the purpose of the study, they were translated into French and slightly reworded to be more child-friendly. For example, the item “I mind-wander during lectures or presentations” was written as “During lessons, I think about unrelated things”. The item “It is difficult for me to alternate between two different tasks” was reworded “It is difficult for me to juggle between two things to do”.

Table 4.1. Measures from the school survey selected for the present study.

QUESTIONS	CODE
Reactions to noise	
Do you think your classroom is noisy? <i>(1) Not noisy at all to, (2) A bit noisy, (3), Quite noisy, (4) Very noisy</i>	C_NOISE_WORD
Do you think that the noise level in class is... <i>(1) Very low, (2) Quite low, (3) Quite loud, (4) Very loud</i>	C_NOISE_LEVEL
On a scale from 0 to 10, how would you estimate the noise level in class to be?	C_NOISE_SCALE
In general, in class, you find your classmates... <i>(1) Not at all noisy, (2) A bit noisy, (3) Quite noisy, (4) Very noisy</i>	NOISY_OTHERS
Are you annoyed by noise in the classroom? <i>(1) Not at all annoyed, (2) A bit annoyed, (3) Quite annoyed, (4) Really annoyed.</i>	NOISE_ANNOY

When the teacher, or a classmate talks to the entire classroom...

You have difficulties hearing what the person says	HEARING_FAR
You are annoyed by noise in the classroom	ANNOY_FAR
Classroom noise attracts your attention	ATTENTION_FAR
If noise attracts your attention, you lose track of the discussion	INTERFERENCE_FAR

Response format: (1) Almost never, (2) Rarely, (3) Quite often, (4) Very often

When the teacher, or a classmate comes closer to talk to you...

You have difficulties hearing what the person tells you	HEARING_CLOSE
You are annoyed by noise in the classroom	ANNOY_CLOSE
Classroom noise attracts your attention	ATTENTION_CLOSE
If noise attracts your attention, you lose track of the discussion.	INTERFERENCE_CLOSE

Response format: (1) Almost never, (2) Rarely, (3) Quite often, (4) Very often

When you do homework on your own

You are annoyed by noise in the classroom	ANNOY_EX_ALONE
Classroom noise attracts your attention	ATTENTION_EX_ALONE
If noise attracts your attention, you lose track of your thoughts.	INTERFERENCE_EX_ALONE

Response format: (1) Almost never, (2) Rarely, (3) Quite often, (4) Very often

When you do homework in a group

You are annoyed by noise in the classroom	ANNOY_EX_GROUP
Noise coming from outside of the group attracts your attention	ATTENTION_EX_GROUP
If noise coming from outside the group attracts your attention, you lose track of the discussion.	INTERFERENCE _EX_GROUP

Response format: (1) Almost never, (2) Rarely, (3) Quite often, (4) Very often

Cognitive predictors

Switching

I am slow to switch from one task to another.	SW_1
It takes me a while to get really involved in a new task.	SW_2
It is difficult for me to alternate between two different tasks.	SW_3
After being interrupted, I have a hard time shifting my attention back to what I was doing before.	SW_4

Response format: (1) Not at all true, (2) A bit true, (3) Quite true, (4) Totally true

Mind-wandering

I have difficulty maintaining focus on simple or repetitive work	MW_1
While reading, I find I haven’t been thinking about the text and must therefore read it again	MW_2
I do things without paying full attention	MW_3
I find myself listening with one ear, thinking about something else at the same time	MW_4
I mind-wander during lectures or presentations	MW_5

Response format: (1) Almost never, (2) Rarely, (3) Quite often, (4) Very often

4.2.4. Results**4.2.4.1. Descriptive statistics**

Descriptive statistics are reported in Table 4.2. One key feature of this data set is that children were nested within classrooms: They shared the same teacher, the same environment, and

were thus able to influence each other. That is to say, observations could not be completely independent. Intra-class correlation coefficients were computed for each variable in order to express the proportion of variance that was attributable to classes (Dorman, 2008; Field, 2018), and are reported in Table 4.2. Intra-class correlation coefficients above 10% can be considered to be a cause of concern (Byrne, 2013). However, the number of classrooms in the sample is too small to compute accurate parameters estimates at both the intra-group and inter-group levels. Since individual noise sensitivity and cognitive abilities were the focus of the study, every child's score was centred on the classroom's mean to remove between-classrooms variance and obtain unbiased estimates at the individual level (Bell, Jones, & Fairbrother, 2017; Cheslock & Rios-Aguilar, 2011).

Table 4.2. Descriptive statistics for all the variables in Chapter 4

	<i>n</i>	<i>Range</i>	<i>M</i>	<i>SD</i>	<i>Skewness</i>	<i>Kurtosis</i>	<i>ICC</i>
Reactions to noise							
Noise levels in the classroom							
C_NOISE_WORD	104	1-4	2.91	.85	-.12	-1.01	10.91
C_NOISE_LEVEL	104	1-4	2.94	.65	-.59	1.23	10.55
C_NOISE_SCALE	98	2-10	6.48	1.86	-.15	-.39	18.19
NOISY_OTHERS	103	1-4	2.73	.78	.02	-.57	0
Reported hearing difficulties							
HEARING_FAR	102	1-4	1.43	.82	1.96	3.07	10.83
HEARING_CLOSE	103	1-4	1.68	.85	1.15	.63	2.31

Attention capture

ATTENTION_FAR	102	1-4	2.29	.91	.19	-.74	8.35
ATTENTION_CLOSE	101	1-4	2.23	.94	.27	-.81	14.41
ATTENTION_EX_ALONE	103	1-4	2.28	.98	.29	-.91	6.08
ATTENTION_EX_GROUP	99	1-4	1.90	.92	.77	-.28	1.50

Interference

INTERFERENCE_FAR	100	1-4	2.22	1.04	.37	-1.03	13.25
INTERFERENCE_CLOSE	102	1-4	2.06	.97	.54	-.72	3.69
INTERFERENCE_EX_ALONE	103	1-4	2.24	1.05	.32	-1.10	8.61
INTERFERENCE_EX_GROUP	101	1-4	1.95	.97	.63	-.72	0

Annoyance

NOISE_ANNOY	103	1-4	2.12	.92	.61	-.34	9.26
ANNOY_FAR	104	1-4	2.35	.96	.25	-.86	0
ANNOY_CLOSE	103	1-4	2.24	1.04	.39	-1.00	0
ANNOY_EX_ALONE	102	1-4	2.41	1.06	.13	-1.18	5.80
ANNOY_EX_GROUP	99	1-4	1.98	.97	.59	-.73	4.03

Cognitive predictors**Switching**

SW_1	102	1-4	3.17	.91	-.98	.21	0.53
SW_2	98	1-4	3.23	.76	-.71	.04	1.82
SW_3	102	1-4	2.81	1.01	-.43	-.89	7.77
SW_4	103	1-4	2.49	1.10	-.08	-1.32	0.00

Mind-wandering

MW_1	100	1-4	1.74	.96	1.04	-.10	2.27
MW_2	102	1-4	2.00	1.04	.64	-.84	7.94
MW_3	100	1-4	1.78	.79	.67	-.29	10.66
MW_4	101	1-4	1.98	.92	.52	-.70	2.28
MW_5	102	1-4	1.75	.91	.92	-.21	13.24

ICC: Intra-class Correlation Coefficient; SW: Switching; MW: Mind-Wandering

Overall, 9.25% of data points were missing, due to children's absence or mistakes in writing in the booklets. Little's (1988) MCAR test was nonsignificant ($\chi^2(593) = 614.28, p = .26$), indicating that data were missing completely at random. The following analyses used the maximum likelihood estimation to deal with missing data (Schreiber, Nora, Stage, Barlow, & King, 2006), and the robust estimator in Mplus 6.12, which does not assume normal multivariate distributions.

4.2.4.2. Factorial analyses

First, an exploratory factorial analysis was carried out on the measures related to children’s reactions to noise, in order to identify whether the items would correspond to the five categories that were defined *a priori*. Geomin rotation was used since factors were expected to be correlated (Kjellberg et al., 1996). Following Boman and Enmarker (2004), inclusion criteria for the factors were eigenvalues > 1 and at least two items with loadings > .50. This led to the five-factors solution reported in Table 4.3.

Table 4.3. Factor loadings of the items assessing children’s reactions to noise (EFA)

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
	Noise	Attention	Hearing	Interference	Annoyance
	levels	capture	difficulties		
C_NOISE_WORD	.84	-.04	.04	-.03	.00
C_NOISE_LEVEL	.73	.00	-.00	.13	.00
NOISY_OTHERS	.63	-.02	-.02	.06	.14
[C_NOISE_SCALE]	.27	.16	-.09	.04	.18
ATTENTION_FAR	-.13	.82	-.11	.18	-.01
ATTENTION_CLOSE	-.01	.82	.13	.06	-.03
ATTENTION_EX_ALONE	.10	.78	.04	-.06	.14
[ATTENTION_EX_GROUP]	-.21	-.07	.20	.32	.37
HEARING_FAR	-.01	.14	.71	-.01	-.05
HEARING_CLOSE	.06	-.02	.73	.02	.06
INTERFERENCE_FAR	.03	.01	-.08	1.03	-.04
INTERFERENCE_CLOSE	.17	.21	.04	.64	.01
INTERFERENCE_EX_ALONE	.08	.19	.05	.34	.18
INTERFERENCE_EX_GROUP	-.10	.10	.22	.40	.09
NOISE_ANNNOY	.13	.02	.02	-.05	.66
ANNNOY_FAR	.03	-.01	-.03	.02	.90
ANNNOY_CLOSE	.04	.20	-.06	-.07	.78
ANNNOY_EX_ALONE	-.01	.27	.02	.02	.64
ANNNOY_EX_GROUP	-.11	-.04	.10	.13	.60

EFA: Exploratory Factorial Analysis

One item did not have any factor loading > .30 on any factor (C_NOISE_SCALE), and one item had loading > .30 on more than one factor (ATTENTION_EX_GROUP). These items were removed from further analyses.

A Confirmatory Factorial Analysis on the remaining 17 items yielded a model with adequate fit ($\chi^2(109) = 159.28, p = .001, CFI = .93, TLI = .91, SRMR = .08, RMSEA = .07$, 90% confidence interval [.04, .09]). Adequate indices of fit are indicated by a low and nonsignificant χ^2 value (however, a big sample size often leads to a significant value), a Comparative Fit Index (CFI) above .9, a Tucker-Lewis Index (TLI) above .9, Standardised Root Mean Square Residual (SRMR) under .08, and a Root Mean Square Error of Approximation (RMSEA) under .08, ideally .05 (Wang & Wang, 2012).

Correlations between factors are reported in Table 4.4. All the factors were moderately to highly correlated to each other, with two exceptions: children’s estimations of noise levels in the classroom did not significantly correlate with their reported difficulties to hear, neither with the tendency for noise to capture their attention.

Table 4.4. Correlations between the factors extracted from the questionnaire assessing children’s reactions to noise

	Factor 2	Factor 3	Factor 4	Factor 5
Factor 1: Noise levels	.04	.15	.29*	.45***
Factor 2: Reported Hearing Difficulties		.30**	.36**	.38**
Factor 3: Attention Capture			.65***	.41***
Factor 4: Interference				.32**
Factor 5: Annoyance				

* $p < .05$; ** $p < .01$; *** $p < .001$

4.2.4.3. Structural Equation models

Factor analyses indicated that noise Interference and Annoyance could be distinguished as two separate, yet correlated factors. The next step was to compute three Structural Equation models corresponding to Figures 4.3.c, 4.4 and 4.5. All three models included a direct effect on Annoyance from our predictor of interest (reported difficulties with hearing, mind-wandering and switching skills, respectively), and an indirect effect through Interference.

The first model (Figure 4.6), focused on reported difficulties with hearing, had a good model fit ($\chi^2(41) = 56.28$, $p = .06$, CFI = .96, TLI = .94, SRMR = .07, RMSEA = .06, 90% confidence interval [.04, .10]). The model explained 18.3% of the variance in Annoyance scores, and 11.6% of the variance in Interference scores. Reported hearing difficulties significantly predicted both Interference and Annoyance. The sum of indirect effects from Reported

hearing difficulties to Annoyance through Interference was estimated at .07 and was not statistically significant ($p = .15$).

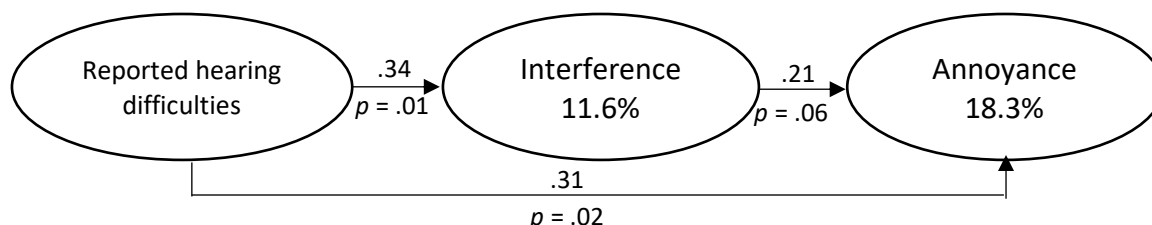


Figure 4.6. Structural Equation Model depicting the direct effect of Reported hearing difficulties on noise Interference and Annoyance, as well as the indirect effect on Annoyance through Interference

The second model, focused on mind-wandering, had adequate fit ($\chi^2(74) = 109.57$, $p = .004$, CFI = .91, TLI = .89, SRMR = .08, RMSEA = .07, 90% confidence interval [.04, .09]), although the relatively low TLI might indicate that it is not very parsimonious. As shown in Figure 4.7, mind-wandering directly predicted noise Interference, but not Annoyance. The sum of indirect effects from Mind-wandering to Annoyance, through Interference, reached .26, with a pvalue of .08. The model predicted 40.4% of the variance in Interference scores, and 10.7% of the variance in Annoyance scores.

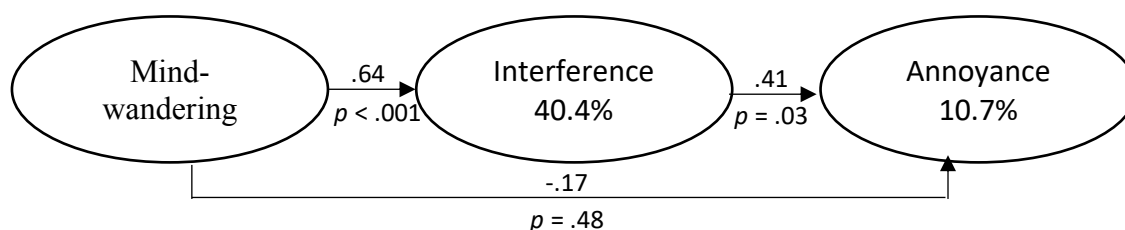


Figure 4.7. Structural Equation Model depicting the direct effect of Mind-wandering on noise Interference and Annoyance, as well as the indirect effect on Annoyance through Interference

The third model (Figure 4.8), related to switching skills, had good fit ($\chi^2(62) = 83.43, p = .04$, CFI = .95, TLI = .93, SRMR = .08, RMSEA = .06, 90% confidence interval [.02, .09]) and indicated a direct effect on both Interference and Annoyance. The sum of the indirect effects from Switching skills to Annoyance was estimated at .10 and was not statistically significant ($p = .47$). Overall, the model explained 40.8% of the variance in Interference scores and 41.4% of the variance in Annoyance scores.

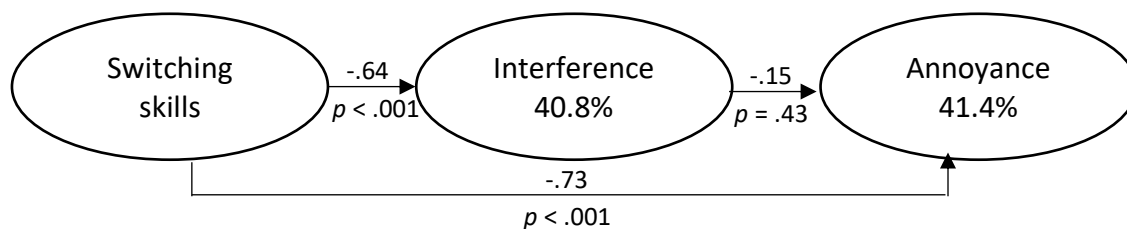


Figure 4.8. Structural Equation Model depicting the direct effect of Switching skills on noise Interference and Annoyance, as well as the indirect effect on Annoyance through Interference

4.2.5. Discussion

In the present study, 8- to 11-year-old children were asked to share their reactions about classroom noise. On average, they found their classroom quite noisy, and they were moderately annoyed by noise (their overall ratings were close to the ratings of irritation by noise by 13- to 14-year-olds in Enmarker and Boman, 2004’s study).

Results from factorial analyses showed that being annoyed by noise and experiencing interference with learning activities formed two correlated yet distinguishable dimensions.

This is in line with Kjellberg et al. (1996)’s empirical results on an adult population. It also fits with Stallen (1999)’s theoretical suggestion that annoyance reactions contain an emotional component that goes beyond the fact that, on a cognitive level, noise causes difficulties with achieving on-going goals and tasks. However, this distinction between Annoyance and Interference was not found by Boman and Enmarker (2004). This could be due to the different items included in the latter analyses. The general factor of Annoyance reported by Boman and Enmarker (2004) included questions about the difficulty with concentrating on an ongoing task, and about the influence of noise on workload, which could be considered to represent interference. Another item related to the level of irritation by noise matched the definition of annoyance (e.g. expressing a negative feeling). Three more items were more ambiguous, reflecting disturbance, surprise, and “thinking about noise”. It is unclear whether these items described a process of interference with one’s thoughts, the fact of having noticed the noise, and/or an emotional reaction, and this could explain why a quite broad annoyance factor was extracted.

In the current study, the factor of Interference specifically targeted the fact that noise was conflicting with an ongoing activity, making children losing track of their thoughts, work, or of an ongoing discussion in the classroom. This was different from simply noticing noise, as reflected in our factor of Attention Capture.

The distinction between the Interference and Annoyance constructs helped to better understand inter-individual differences in the children’s reactions to noise. Children who reported greater difficulties in hearing in the classroom, and in switching from one task to another, reported more Interference and Annoyance from noise. Children who had a greater

propensity to let their minds wander also experienced more Interference from noise, but were not necessarily annoyed by it.

Overall, children reported few difficulties with hearing when the teacher (or a classmate) was talking to them or to the entire classroom. There was, however, some inter-individual variability, with some children reporting more frequent hearing difficulties. For these children, noise seems to interrupt their ongoing activity, and to be particularly annoying. Three out of the four classroom activities that were included in the questionnaire require listening to other people, when 1) the teacher or a classmate talk to the entire classroom, 2) the teacher or a classmate talk to the respondent, 3) the respondent is engaged in group work. Children reporting hearing difficulties might have troubles to understand speech in noise, and might therefore lose track of the messages that are being communicated.

However, hearing difficulties seem to predict Interference and Annoyance by two separate and direct pathways. The indirect effect on Annoyance through Interference was not significant. In other words, results do not show that noise is annoying for children to the extent that it interrupts their ongoing task. Annoyance ratings could reflect children's overall frustration with communication and listening difficulties. Note that the assessment of hearing difficulties in the present study was subclinical and relied on self-report, since the number of children clinically referred for hearing problems (one) was too small to allow for group comparisons within this sample. However, and in line with Boman and Enmarker (2004) results suggest that hearing difficulties considered on a continuum can help explaining inter-individual variability in children's reactions to noise.

Beyond hearing processes, the current study included a questionnaire about switching skills, with the aim of better understanding the cognitive mechanisms behind noise interference. Children with lower switching skills reported having difficulties in moving from one task to another, or in re-focusing on an activity after having been interrupted. Results indicated that those children tend to lose track of a discussion more easily in the presence of noise, and also to have difficulties focusing on their own thoughts when engaged in solo work. This is in line with Carriere et al. (2013)’s findings on an adult population. Switching skills rely on the capacity to inhibit unwanted representations (also known as inhibitory control), and on working memory, to “load” representations for the task of interest (Diamond, 2013). Good inhibitory control and working memory have been identified as two protective factors reducing the impact of noise on performance, as assessed in behavioural tasks (Massonnié, Rogers, Mareschal, & Kirkham, 2019; Sörqvist, 2010b; Sörqvist, Halin, & Hygge, 2010, also see results from Chapter 2). Future studies assessing children’s switching skills with behavioural as well as self-report tasks might help to bridge a gap between these two strands of research, while allowing for a better understanding of the processes underlying noise interference.

It is worth noting that, in line with the results of hearing difficulties, there was no indirect effect of switching difficulties on Annoyance through Interference. Instead, there seem to be two, relatively independent direct effects. Some strategies to reduce noise annoyance might involve a re-evaluation of the noise source (Guski, 1999; Stallen, 1999), for example, perceiving an external conversation as a social signal instead of an intrusion to privacy. This would require to flexibly change perspective, which is a component of switching skills (Diamond, 2013). Qualitative studies might be insightful to better understand children’s attitudes and annoyance reactions (Haines, Brentnall, Stansfeld, & Klineberg, 2003).

A coping mechanism mentioned by children in Boman and Enmarker (2004)'s and Haines, Brentnall, Stansfeld, and Klineberg (2003)'s interviews is to disappear into daydreams, or to think about something other than the noise. Our data indicate that pupils' propensity to let their minds wander did not directly predict their level of annoyance with noise. Instead, an indirect effect was reported, mind-wandering leading to more Annoyance via more Interference. This indirect effect was tenuous, since it was not significant at the .05 level.

The direct effect from more mind-wandering to greater noise interference is in line with theoretical (McVay & Kane, 2010) and empirical (Carriere et al., 2013; Forster & Lavie, 2014) accounts of mind-wandering as reflecting a lack of attentional control. In that sense, mind-wanderers would have difficulties to focus on their thoughts, or on an ongoing discussion in the presence of ambient noise. Note that this could reflect a lack of inhibition similar to that experienced by children with switching difficulties. In their study, Carriere, et al. (2013) reported a positive correlation between adults' self-report measures of mind-wandering and their switching difficulties.

Overall, a higher percentage of variance in children's reactions to noise was explained by cognitive processes (switching and mind-wandering), compared to sensory processes (difficulties with hearing). This is in line with studies showing that acoustical factors only partly explain inter-individual differences in adults' reactions to noise (Ellermeier et al., 2001; Stansfeld, Clark, Turpin, et al., 1985). In particular, Ellermeier et al. (2001) used a combination of seven psychoacoustical tasks (measuring hearing thresholds, or judgement of loudness, for example), and found that they explained around 15% of participants' reactions to noise in everyday life. Although the current study focused on children's self-report hearing difficulties, and not on acoustical tasks, it yielded similar results, explaining 11.6% of the variance in noise

Interference, and 18.3% of the variance in noise Annoyance. The present study suggests to have a closer look at attentional control and working memory, two skills involved in switching (Diamond, 2013) and mind-wandering (McVay & Kane, 2010).

4.3. Conclusion and future directions

Results from this school survey suggest that experiencing interference from noise when engaged in a learning task, and being annoyed by noise do not fully overlap. Children who reported greater difficulties to hear in the classroom, and to switch from one task to another, reported more Interference and Annoyance from noise. Children who had a greater propensity for mind-wandering also experienced more interference from noise, but they were not necessarily annoyed by it. The distinction between Annoyance and Interference has theoretical, empirical, and practical relevance for educational research. These two types of reactions to noise might reflect different constructs, underlined by different mechanisms, which might help to better understand inter-individual differences in the classroom.

Findings suggest a role of executive functions when experiencing interference from noise. Indeed, children who had a greater propensity to let their minds wander and who reported greater difficulties in switching from one task to another reported more Interference from noise. Both switching skills and mind-wandering have been related to executive function processes, and in particular inhibition and working memory. Chapter 5 will therefore test whether children’s reports of noise interference relates to their level of executive functions.

Chapter 5 - Children’s reactions to classroom noise and executive
functions

5.1. Chapter overview

In Chapter 4, it was reported that children’s reactions to noise in classroom settings had five dimensions. The overall tendency to judge the classroom noisy (or not) and reported difficulties with hearing were the first two. When children were engaged in learning activities, three different effects of noise were noticed: Attention Capture (the fact that noise captured pupils’ attention), Interference with an ongoing activity (noise making pupils lose track of their thoughts, or of a discussion), and finally, Annoyance.

Children reporting more difficulties to hear, worse switching skills, and a greater tendency to let their minds wander experienced more Interference from noise. In addition, both switching and hearing difficulties predicted greater Annoyance towards noise, but switching skills explained a greater amount of variance. All the measures used in Chapter 4 were based on self-report.

Relating children’s reactions to noise to behavioural executive function tasks might help explain their underlying cognitive processes, while also bridging the gap between survey-based and experimental methods. Consequently, this is the aim of Chapter 5. Associations between children’s reactions to noise and behavioural assessments of sustained attention, inhibitory control, and verbal working memory were tested using the sample of children from Experiment 3.

The approach used in Chapter 5 is shown in Figure 5.1. Children’s reactions to noise were based on self-report. Individual, laboratory-based measures of attention were included. Working memory was assessed with a collective task carried out in the classroom.

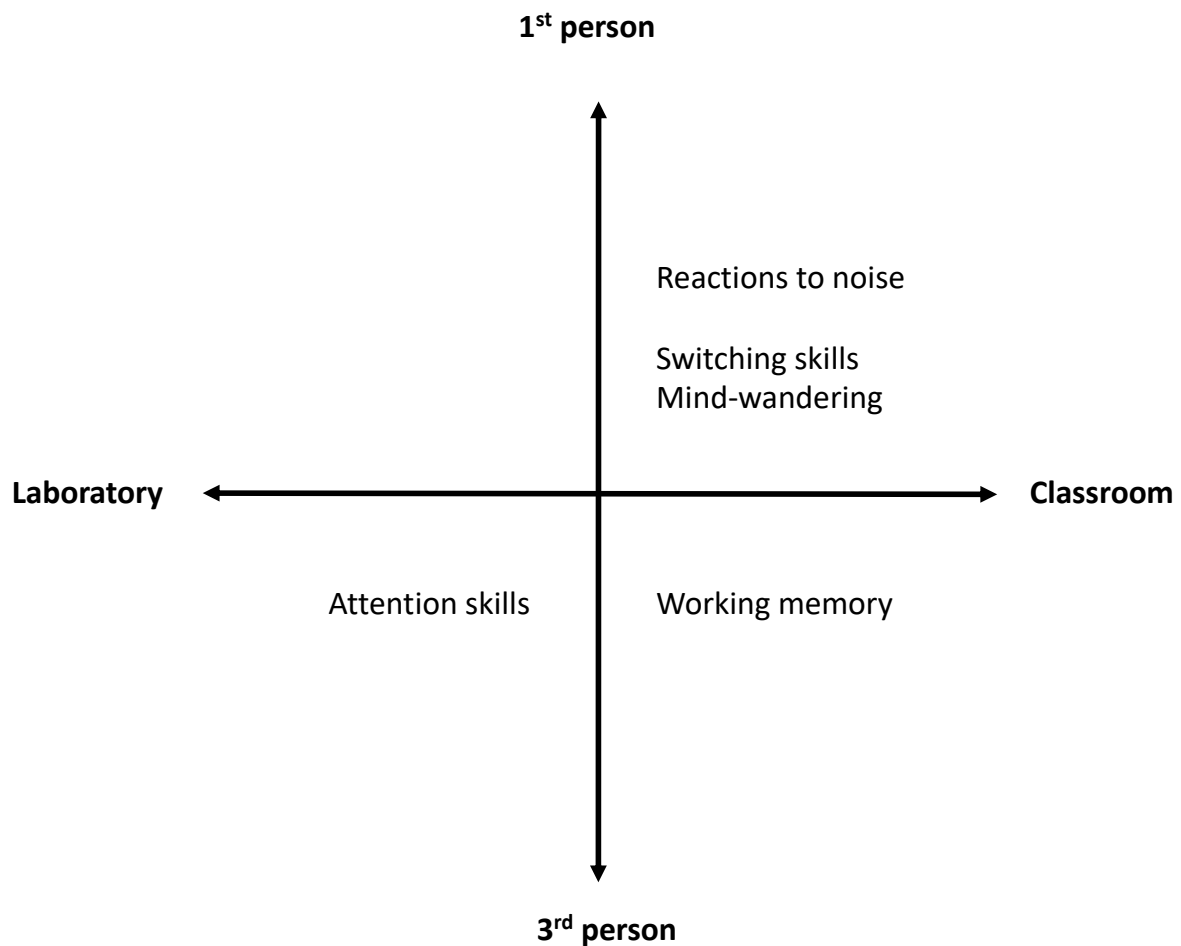


Figure 5.1. Methodological approach used in Chapter 5

5.2. Experiment 3: Children’s reactions to classroom noise and executive functions

5.2.1. Introduction

In Chapter 4, children who reported difficulties switching from one task to another and a greater propensity for mind-wandering also experienced more Interference from noise when engaged in learning tasks. Given that worse switching skills are correlated with more mind-wandering (Carriere et al., 2013), some common mechanisms may underlie these feelings of interference. People who tend to let their minds wander more frequently, and who have difficulties in switching from one task to another, could also have troubles focusing their attention on an ongoing task while keeping their goals in mind. In other words, they might have a lower working memory, and a lower inhibitory control.

This idea is supported by theoretical models of executive functions highlighting the interdependency between switching skills, working memory and inhibitory control (Diamond, 2013; Miyake et al., 2000). Efficiently switching from one task to another requires both working memory resources (the ability to keep goals in mind while manipulating thoughts and being exposed to external stimuli), and inhibitory control skills, in order to actively select what to pay attention to, resist impulses and avoid distraction.

Adult studies show that better working memory and attentional skills are also associated with less mind-wandering. Undergraduate students with better working memory skills mind-wander less frequently while reading a text, which in turn predicts better reading comprehension (Unsworth & McMillan, 2013). Whereas undergraduate students with higher

working memory skills stay on task whatever the level of challenge and effort, those with low working memory skills mind-wander more during challenging and effortful tasks (Kane et al., 2007). Mind-wandering has also been associated with more distraction from task-irrelevant visual distractors (Forster & Lavie, 2014), and with more reaction time variability at sustained attention to response tasks (McVay & Kane, 2009; 2012). In these types of tasks, participants have to respond as quickly as possible to a certain type of stimulus (e.g. the letter O), and to withhold their response for another stimulus (e.g. the letter X). A greater variability in reaction time when responding to targets can indicate attentional fluctuations, both within typically developing participants, and when comparing typically developing participants with children and adults diagnosed with attention deficit hyperactivity disorder (Epstein et al., 2011; for a review, see Kofler et al., 2013). Based on its associations with working memory and attentional control, some authors have conceived mind-wandering as a failure of executive processes (McVay & Kane, 2010).

Studies about mind-wandering show the complementarity of self-report and behavioural methodologies. Mind-wandering is in itself a subjective experience, and it would not be possible to have access to participants’ thoughts without directly asking them. However, analysing how mind-wandering relates to performance on other behavioural tasks helps to better understand its underlying mechanisms.

Bridging the gap between survey and task-based methodologies would add a lot to the noise literature. Surveys, discussions and interviews need to be done to recognise children’s subjective reactions to noise, and to promote their well-being. As with mind-wandering, a feeling of being distracted can be associated with attentional difficulties, or a high working

memory load. Understanding these connections can help develop ways to alleviate children’s frustrations in the face of noise, tapping in to these attentional and memory processes (Diamond & Lee, 2011; Diamond & Ling, 2016). So far, a connection between the survey and behavioural data is lacking in the noise literature. On the one hand, behavioural studies investigating the role of executive functions when working in noise do not measure participants’ subjective reactions to noise (Beaman, 2004; Sörqvist, 2010a, 2010b; Sörqvist, Halin, et al., 2010; Sörqvist, Ljungberg, et al., 2010). On the other hand, survey-based studies assessing children’s and adults’ reactions to noise do not test their relation with executive function processes (Boman & Enmarker, 2004; Evans et al., 1995; Haines & Stansfeld, 2000; Haines et al., 2001; Kjellberg et al., 1996; Lercher et al., 2000; Stansfeld et al., 2005).

5.2.2. Aims of the current investigation

The present study assessed whether behavioural tasks of sustained attention, inhibitory control and working memory are associated with children’s subjective reactions to noise. It focuses on the dimensions of Attention Capture, Interference and Annoyance, since they reflect children’s reactions to noise when engaged in a specific task (either listening to someone in the classroom, or doing homework).

Measures of inhibitory control and working memory were hypothesised to be related to children’s reports of Attention Capture and Interference from noise. However, laboratory tests of executive functions were not expected to relate to reactions of Annoyance. Indeed, as discussed in Chapter 4, noise Annoyance might be associated with emotional states and specific attitudes towards the source of noise, not just to attentional skills *per se*. In addition,

and to connect results with the literature on mind-wandering and switching skills, direct associations between these two skills (as measured by questionnaires, as in Chapter 4), and executive functions were tested.

5.2.3. Methods

5.2.3.1. Participants

The sample is identical to that of Chapter 4, including 112 typically-developing pupils from 8.70 to 11.38 years of age ($M = 10.03$; $SD = .60$). The project received ethical approval from both the Departmental and College Ethics Committees. Following an opt-in procedure, all the participants gave verbal consent to participate, and written informed consent was obtained from their guardian. The study was conducted in accordance with the Declaration of Helsinki. The participating classrooms were under the jurisdiction of a French educational inspector who approved the ethical guidelines of the study.

5.2.3.2. Procedure

Children were tested in both individual and collective sessions. Individual sessions lasted around 15 minutes and included the three attentional tasks in the same fixed order: 1) the Letter Cancellation task, 2) the Flanker task, and 3) the Sustained Attention to Response Task (SART). Verbal working memory and children’s reactions to noise were assessed in a group setting. Children were tested in their usual classroom, under the supervision of their teacher.

For a given school, individual and collective sessions were carried out the same week. Testing the entire sample took two weeks and a half.

5.2.3.3. Measures

Children’s reactions to noise were measured with the school survey presented in Chapter 4 (see Appendix D and https://drive.google.com/drive/folders/10_Kv9d-uO07ww_Mxum5YaLbSCqdC2vrN). Attention capture, Interference and Annoyance from noise were assessed based on the questions extracted from the factorial analyses in Chapter 4 (see section 4.2.4.2 and Table 4.2). Attention Capture was measured using three items, Interference by four items, and Annoyance by five items.

Switching skills and **mind-wandering** were measured in the same way as in Chapter 4.

Inhibitory control was assessed with the same Flanker task as described in Chapters 2 and 3 (Anwyl-Irvine, Massonnié, Flitton, Kirkham, & Evershed, 2019; adapted from Rueda et al., 2004). A horizontal row of five cartoon fish was presented in the centre of the screen, and participants had to indicate the direction the middle fish was pointing (either to the left, or right). In *congruent* trials, the middle fish was pointing in the same direction as the flanking fish. In the *incongruent* trials, the middle fish was pointing in the opposite direction. Instructions were translated into French. Accuracy (the proportion of correct trials) and Reaction Times for correct answers (RTs) for congruent and incongruent trials were recorded.

Sustained attention was measured with a Sustained Attention to Response Task (SART), and a Letter Cancellation task.

The SART corresponded to a “Whack a mole” game. Participants were required to press the space bar when they were presented with a picture of a mole (Go trials) but not when they were presented with a picture of an eggplant (No Go trials; see Figure 5.2). Go trials were more frequent than No Go trials to induce a prepotent response (76% Go trials, 24% No Go trials). Children first had five practice trials with immediate feedback from the experimenter. The task then included 90 randomly presented trials split into 3 blocks, with no feedback. The trial sequence was pseudorandomized. There were never two or more No Go trials in a row, and the number of Go trials before a No Go trial varied between 1 and 5. Each trial was displayed for 1300ms. The proportion of correct answers at the Go trials and the reaction time for correct answers at the Go trials were recorded. For each subject, the standard deviation of their reaction time distribution was recorded as a measure of reaction time variability (McVay & Kane, 2012).



Figure 5.2. Go trial (left panel) and No Go trial (right panel) from the Sustained Attention to Response Task

In the Letter Cancellation task, adapted from Casco, Tressoldi, & Dellantonio (1998), children were asked to scan a A4 paper sheet from the top left corner to the bottom right corner, row by row, and to cross all the “T” and “G”. The paper sheet contained 336 letters, printed in 21 rows of 16 (see Appendix E). Each letter of the alphabet was represented 12 or 13 times, and there were 26 targets, corresponding to 7.74% of the stimuli. Children were asked to go as fast as possible, and, under the supervision of the experimenter, they were prevented from going back to a row that was already scanned. The number of targets correctly identified, as well as the total time in seconds, were recorded. A composite performance score taking into account both speed and accuracy was then computed and used in further analyses. It was calculated as follow: (number of correct responses/number of targets) x (number of correct responses/total time), see Geldmacher (1996). Higher scores indicate better performance. Following discussions with teachers, it appeared that this measure was more representative of what they conceived as “paying attention to an exercise” in the classroom, compared to computer-based tasks focused on short reaction time.

Verbal working memory was assessed with a backward digit span task. Children were presented with series of digits through speakers. They were instructed to “raise their pencils” while the list was displayed (to make sure they would not write at the same time). Then, they had to report the digits back, in reversed order, on their individual booklet. List lengths evolved from two, to eight digits. Children were presented with four trials of a given list length. Since the task was performed in a group session, all children were exposed to 28 trials. Stopping rules were applied *a posteriori*, following the rules used in Chapters 2 and 3: scoring

stopped when children missed more than one trial for a given level. The final score corresponded to the total number of correct answers given before this stopping rule.

5.2.4. Results

5.2.4.1. Pre-processing of the behavioural tasks

Inhibitory control

Accuracy was at ceiling for both the congruent ($M = 98.50\%$) and the incongruent ($M = 98.39\%$) trials of the Flanker task. Therefore, reaction times for correct answers (RTs) were retained as the main outcome of interest. RTs under 200ms (being too short to follow the perception of the stimuli), and above 3 standard deviations from the mean of each subject were excluded (Koivisto & Grassini, 2016; Rutiku et al., 2016; Whelan, 2008).

One participant had extreme values. Their RTs for congruent trials and incongruent trials were 6.22 and 7.91 standard deviations away from the mean of the sample respectively. The difference in RTs between congruent and incongruent trials for this participant was 8.42 standard deviations away from the mean. This child’s scores were therefore removed from further analyses of the Flanker task in order to avoid this outlier unduly influencing the results.

An analysis of variance, with Congruency (Congruent trials vs Incongruent trials) as a within-subject factor, and Age as a covariate, was carried out. There was a significant main effect of Congruency ($F(1, 107) = 5.35, p = .023, \eta^2_p = .05$). RTs were longer for incongruent trials ($M = 868.97; SD = 200.12$) compared to congruent trials ($M = 823.85; SD = 166.23$). The interaction between Congruency and Age approached significance ($F(1, 107) = 3.85, p = .052$,

$\eta^2_p = .04$). The difference in reaction times between congruent and incongruent trials tended to diminish with age ($r = -.19$; $p = .052$).

Reaction time costs (RTs incongruent trials - RTs congruent trials) were used as the main measure of inhibitory control in further analyses. Higher values indicate poorer inhibitory control, since it takes longer to give the correct answer for incongruent trials compared to congruent trials.

Sustained attention to response task. Accuracy was at ceiling for Go trials ($M = 98.58$; $SD = 2.30$). None of the children performed at chance level (below 60% accuracy). Reaction time variability was calculated on at least 77 trials per child, making it a suitable measure.

Verbal working memory. A close look at the distribution for the working memory scores revealed some inconsistencies. The distribution had a normal, bell-shape curve for scores between 0 and 26, but peaks were noted for scores of 27 and 28 (reflecting a perfect or almost perfect score). Several teachers⁷ reported that children were not closely following the instructions, and were writing down the numbers *as* they heard them (instead of waiting for the list to be finished), and from right to left (to mimic the reversing process). Therefore, only scores below 27 were included. This procedure reduces the sample size available for the working memory task (from $n = 104$ to $n = 80$) and is open to debate. That said, it is the most conservative approach since it only includes in the analyses children known to have engaged with task as instructed. It will be further addressed in the discussion.

⁷ This was also noted anecdotally by the experimenters during occasional visits.

5.2.4.2. Descriptive statistics

Descriptive statistics (calculated after the filtering process described above), are in Table 5.1.

Table 5.1. Descriptive statistics for all the variables in Chapter 5

	<i>n</i>	<i>Min</i>	<i>Max</i>	<i>M</i>	<i>SD</i>	<i>Skewness</i>	<i>Kurtosis</i>	<i>ICC</i>
Reactions to noise								
Attention capture								
ATTENTION_FAR	102	1	4	2.29	.91	.19	-.74	8.35
ATTENTION_CLOSE	101	1	4	2.23	.94	.27	-.81	14.41
ATTENTION_EX_ALONE	103	1	4	2.28	.98	.29	-.91	6.08
Interference								
INTERFERENCE_FAR	100	1	4	2.22	1.04	.37	-1.03	13.25
INTERFERENCE_CLOSE	102	1	4	2.06	.97	.54	-.72	3.69
INTERFERENCE_EX_ALONE	103	1	4	2.24	1.05	.32	-1.10	8.61
INTERFERENCE_EX_GROUP	101	1	4	1.95	.97	.63	-.72	0
Annoyance								
NOISE_ANNOY	103	1	4	2.12	.92	.61	-.34	9.26
ANNOY_FAR	104	1	4	2.35	.96	.25	-.86	0
ANNOY_CLOSE	103	1	4	2.24	1.04	.39	-1.00	0
ANNOY_EX_ALONE	102	1	4	2.41	1.06	.13	-1.18	5.80
ANNOY_EX_GROUP	99	1	4	1.98	.97	.59	-.73	4.03

Table 5.1. (Continued)

Switching and mind-wandering								
Switching								
SW_1	102	1	4	3.17	.91	-.98	.21	0.53
SW_2	98	1	4	3.23	.76	-.71	.04	1.82
SW_3	102	1	4	2.81	1.01	-.43	-.89	7.77
SW_4	103	1	4	2.49	1.10	-.08	-1.32	0
Mind-wandering								
MW_1	100	1	4	1.74	.96	1.04	-.10	2.27
MW_2	102	1	4	2.00	1.04	.64	-.84	7.94
MW_3	100	1	4	1.78	.79	.67	-.29	10.66
MW_4	101	1	4	1.98	.92	.52	-.70	2.28
MW_5	102	1	4	1.75	.91	.92	-.21	13.24
Executive functions								
Inhibitory control (Flanker)	109	- 89.30	560	45.12	33.48	3.22	16.28	2.07
Sustained attention (SART)	110	61.48	165.44	101.55	19.73	.54	.39	1.75
Sustained attention (LCT)	110	.05	.28	.14	.04	.49	.66	8.30
Verbal Working memory	80	0	26	11.48	6.23	.52	.15	0

ICC: Intra-class Correlation Coefficient; SART: Sustained Attention to Response Task; LCT: Letter Cancellation Task

Since children were nested within classrooms, and since the number of classrooms in the sample was too small to compute accurate parameters estimates at both the intra-group and inter-group levels, every child's score was centred on the classroom's mean to remove

between-classrooms variance and obtain unbiased estimates at the individual level (Bell et al., 2017; Cheslock & Rios-Aguilar, 2011).

Overall, 9.05% of data points were missing, due to children's absence or mistakes in writing in the booklets. Little's (1988) MCAR test was nonsignificant ($\chi^2 (842) = 834.90, p = .562$), indicating that data were missing completely at random. The following analyses are based on the maximum likelihood estimation to deal with missing data (Schreiber et al., 2006), and on the robust estimator in Mplus 6.12, which does not assume normal multivariate distributions. Correlations between all the variables are reported in Table 5.2.

5.2.4.3. Children’s reactions to noise and executive functions

Structural Equation modelling was carried out to assess whether children’s executive functions predicted their subjective reactions to noise. Models were built to predict Attention Capture, Interference and Annoyance. These three dimensions were defined as latent factors: Attention Capture was composed of three items; Interference of four items, and Annoyance of five items. As can be seen in the correlation table (Table 5.2), the items composing a given factor were moderately to strongly correlated with each other. Each factor was regressed on executive function measures, defined as individual observed variables. That is to say, executive function scores were used as calculated in section 6.2.4.1, and were not combined with each other. A series of three models was performed.

Table 5.2. Correlations between all the variables in Chapter 5

[illegible]

First, each executive function was entered independently, after controlling for Age. This allowed to test for their respective contribution.

Second, all the variables assessing sustained attention, and inhibitory control were entered simultaneously as independent variables. Since MPlus 6.12 does not offer the possibility of conducting hierarchical regressions, only the global R^2 is available. In this way, the contribution of each attention measure was assessed while controlling for the contribution of the other measures.

Third, working memory was added as a predictor, in addition to sustained attention and to inhibitory control. Note that this model was based on a smaller number of participants compared to the model only including attentional tasks. This is because of the data screening process (described above) that was carried out to remove data from 24 children who did not follow the instructions in the Backward Digit Span working memory task.

Model fit was checked for each regression model. Adequate indices of fit are indicated by a low and nonsignificant χ^2 value, a Comparative Fit Index (CFI) above .9, a Tucker-Lewis Index (TLI) above .9, Standardised Root Mean Square Residual (SRMR) under .08, and a Root Mean Square Error of Approximation (RMSEA) under .08 (Wang & Wang, 2012). Results are reported in Tables 5.3, 5.4 and 5.5 below.

Table 5.3. Structural Equation Models predicting Attention Capture by sustained attention, inhibitory control and verbal working memory, controlling for age

	β	p	R^2 (%)	n	χ^2	CFI	TLI	RMSEA	SRMR
Individual models									
1. Age	.09	.424	0.7	103	3.12	.99	.97	.07	.02
2. Inh. control (Flanker)	-.08	.479	1.4	102	2.74	1	1	.00	.02
2. Sustained att. (SART)	.19	.044	4.3	101	3.19	1	1	.00	.02
2. Sustained att. (LCT)	-.07	.603	1.2	101	5.61	.99	.97	.06	.02
2. VWM	-.20	.044	4	76	4.79	.99	.98	.05	.03
Att. model									
1. Age	.11	.284							
2. Inh. control (Flanker)	-.08	.499							
Sustained att. (SART)	.19	.047							
Sustained att. (LCT)	-.06	.658							
			5.3	100	7.14	1	1	.00	.02
Att. and WM model									
1. Age	.05	.675							
2. Inh. control (Flanker)	-.01	.915							
Sustained att. (SART)	.13	.221							
Sustained att. (LCT)	-.14	.275							
VWM	-.16	.164							
			8.2	75	8.41	1	1	.00	.02

Inh.: inhibitory; att.: attention; SART: Sustained Attention to Response Task; LCT: Letter Cancellation Task; VWM: Verbal Working Memory

Attention Capture. Children who reported that noise attracted their attention more frequently in the classroom also had greater variability in reaction time at the SART, and lower verbal working memory (Table 5.3). This was shown by the individual regression models. When all the attentional measures were entered simultaneously, reaction time variability was still a significant predictor of Attention Capture. However, in the full executive function model, no significant predictor could be identified.

Interference. Children who experienced more Interference from noise (i.e. who reported more frequently that noise made them lose track of a discussion, or of their work) also had greater reaction time variability at the SART, and lower verbal working memory (Table 5.4). When all the measures of attention were entered as independent variables, reaction time variability was still a significant predictor of Interference. However, that was not the case when all the executive function tasks were entered in the same model. Only verbal working memory still tended to predict Interference, but this was non-significant.

Annoyance. As shown in Table 5.5, none of the executive function tasks were associated with children’s reactions of Annoyance. That was the case for each set of models.

Table 5.4. Structural Equation Models predicting noise Interference by sustained attention, inhibitory control and verbal working memory, controlling for age

	β	p	R^2 (%)	n	χ^2	CFI	TLI	RMSEA	SRMR
Individual models									
1. Age	.00	.983	0	105	3.84	1	1	.00	.03
2. Inh. control (Flanker)	-.03	.776	0	102	4.97	1	1	.00	.03
2. Sustained att. (SART)	.20	.033	4.1	103	4.47	1	1	.00	.03
2. Sustained att. (LCT)	-.11	.337	1.2	103	6.05	1	1	.00	.03
2. VWM	-.24	.023	5.6	78	5.46	1	1	.00	.03
Att. model									
1. Age	.02	.841							
2. Inh. control (Flanker)	-.03	.785							
Sustained att. (SART)	.20	.038							
Sustained att. (LCT)	-.11	.343							
			5.4	102	8.14	1	1	.00	.03
Att. and WM model									
1. Age	.01	.959							
2. Inh. control (Flanker)	.02	.908							
Sustained att. (SART)	.09	.439							
Sustained att. (LCT)	-.18	.217							
VWM	-.19	.094							
			10.1	77	12.06	1	1	.00	.03

Inh.: inhibitory; att.: attention; SART: Sustained Attention to Response Task; LCT: Letter Cancellation Task; VWM: Verbal Working Memory

Table 5.5. Structural Equation Models predicting noise Annoyance by sustained attention, inhibitory control and verbal working memory, controlling for age

	β	p	R^2 (%)	n	χ^2	CFI	TLI	RMSEA	SRMR
Individual models									
1. Age	.04	.678	0.2	105	2.36	1	1	.00	.02
2. Inh. control (Flanker)	-.13	.176	1.9	102	6.49	1	1	.00	.03
2. Sustained att. (SART)	-.01	.912	0.2	103	5.08	1	1	.00	.03
2. Sustained att. (LCT)	-.06	.600	0.5	103	7.85	1	1	.00	.03
2. VWM	-.03	.814	0.2	78	7.59	1	1	.00	.04
Att. model									
1. Age	.04	.684							
2. Inh. control (Flanker)	-.13	.185							
Sustained att. (SART)	-.02	.871							
Sustained att. (LCT)	-.07	.556							
			2.4	102	14.99	1	1	.00	.03
Att. And WM model									
1. Age	.05	.656							
2. Inh. control (Flanker)	-.13	.292							
Sustained att. (SART)	.01	.911							
Sustained att. (LCT)	-.02	.858							
VWM	-.01	.932							
			1.9	77	22.45	1	1	.00	.04

Inh.: inhibitory; att.: attention; SART: Sustained Attention to Response Task; LCT: Letter Cancellation Task; VWM: Verbal Working Memory

5.2.4.4. Switching, mind-wandering and executive functions

Similar models were carried out to test whether switching skills and mind-wandering were predicted by executive functions. Switching skills and mind-wandering were defined as latent factors, respectively composed of four and five items. As shown in Table 5.2, all the items assessing switching skills (except one) were moderately correlated with each other. Half of the items assessing mind-wandering were moderately correlated with each other. Note that the first item from the mind-wandering scale (“I have difficulty maintaining focus on simple or repetitive work”) was negatively correlated with three items from the switching scale.

Switching. As shown in Table 5.6, none of the executive function tasks predicted switching skills.

Mind-wandering. Individual models showed that mind-wandering was not related to sustained attention, to inhibitory control, or to verbal working memory. As can be seen in Table 5.7, several models did not have good fit: the individual model predicting mind-wandering from the Letter Cancellation Task, the attention model and the full executive function model. They can be identified by significant χ^2 values, low CFI and TLI. This poor fit will be addressed in the discussion. However, note that the higher the tendency for children to think about unrelated things during a lesson, the lower the score at Letter Cancellation Task (Table 5.2). This correlation was specific to the first item of the mind-wandering scale.

Table 5.6. Structural Equation Models predicting Switching skills by sustained attention, inhibitory control and verbal working memory, controlling for age

	β	p	R^2 (%)	n	χ^2	CFI	TLI	RMSEA	SRMR
Individual models									
1. Age	-.07	.583	0.5	105	2.31	1	1	.00	.03
2. Inh. control (Flanker)	.22	.086	4.8	102	4.70	1	1	.00	.04
2. Sustained att. (SART)	-.12	.431	1.6	103	3.26	1	1	.00	.03
2. Sustained att. (LCT)	.02	.910	0.2	103	6.64	1	1	.00	.04
2. VWM	.06	.704	1.2	78	4.13	1	1	.00	.04
Att. model									
1. Age	-.05	.741							
2. Inh. control (Flanker)	.22	.095							
Sustained att. (SART)	-.11	.512							
Sustained att. (LCT)	.06	.686							
			6.2	102	9.94	1	1	.00	.04
Att. And WM model									
1. Age	-.12	.494							
2. Inh. control (Flanker)	.13	.497							
Sustained att. (SART)	-.17	.381							
Sustained att. (LCT)	.06	.703							
VWM	.04	.813							
			6.5	77	17.47	.96	.94	.02	.05

Inh.: inhibitory; att.: attention; SART: Sustained Attention to Response Task; LCT: Letter Cancellation Task; VWM: Verbal Working Memory

Table 5.7. Structural Equation Models predicting Mind-wandering by sustained attention, inhibitory control and verbal working memory, controlling for age

	β	p	R^2 (%)	n	χ^2	CFI	TLI	RMSEA	SRMR
Individual models									
1. Age	.21	.108	4.4	103	9.43	.99	.98	.02	.05
2. Inh. control (Flanker)	-.05	.599	4.1	100	13.71	.98	.97	.02	.05
2. Sustained att. (SART)	.06	.663	4.1	101	13.12	1	.99	.01	.05
2. Sustained att. (LCT)	-.17	.480	6.4	101	28.35**	.66	.48	.11	.07
2. VWM	-.04	.770	8.4	77	15.42	.93	.89	.05	.06
Att. model									
1. Age	.21	.128							
2. Inh. control (Flanker)	-.07	.566							
Sustained att. (SART)	.06	.634							
Sustained att. (LCT)	-.19	.458							
			8.1	100	37.22*	.65	.50	.09	.07
Att. And WM model									
1. Age	.29	.09							
2. Inh. control (Flanker)	-.10	.45							
Sustained att. (SART)	.06	.691							
Sustained att. (LCT)	-.27	.429							
VWM	.04	.798							
			1.5	76	43.33*	.58	.42	.10	.07

Inh.: inhibitory; att.: attention; SART: Sustained Attention to Response Task; LCT: Letter Cancellation Task; VWM: Verbal Working Memory; * $p < .05$; ** $p < .001$

5.2.5. Discussion

Chapter 4 identified the relation between self-report of switching skills and mind-wandering, on one hand, and feelings of distraction in a noisy context, on the other hand. In line with the existing literature, it was suggested that attention and working memory could both underlie switching skills, mind-wandering, and children’s sensation of being distracted. The present study aimed at testing this idea.

Attentional skills were assessed with three tasks, measuring inhibitory control (the Flanker task) and sustained attention (the SART, the Letter Cancellation Task). Children’s scores at these three tasks were not correlated with each other. However, better performance at the Letter Cancellation Task, and a higher interference at the Flanker task were associated with better verbal working memory skills.

There were specific associations between executive function tasks and children’s reactions to noise in classroom settings. Children who reported more frequently that noise captured their attention, and interfered with their ongoing task, also had lower verbal working memory and higher reaction time variability at the SART. These results bridge the gap between self-report, and behavioural assessments of distractibility. Behavioural variability has been conceived as a marker of attentional difficulties, but most studies focus on the comparison between subjects with and without a diagnosis for ADHD (for a review, see Kofler et al., 2013). This is the first study relating primary school children distractibility in the classroom with a measure of behavioural variability, on a neurotypical sample. It should be noted that two items from the Attention Capture and Interference factors were related to the capacity to listening to

someone talking in the classroom, and these two items were individually correlated with measures of sustained attention and working memory. This is in line with behavioural (Conway et al., 2001) and neuroimaging (Adank, 2012; Alain, Du, Bernstein, Barten, & Banai, 2018) studies suggesting a role of attention and working memory when understanding speech in noise. Note, however, that attentional and working memory skills explained less than five percent of the variance in the factors Attention Capture and noise Interference. The attentional measures relied on visual processes, and it is possible that specific measures assessing *auditory* attention would be stronger predictors. Furthermore, a behavioural measure of switching skills, requiring the use of both attention and working memory, could be more strongly related to children’s self-report of distractibility.

Contrary to the results on Attention Capture and Interference, feelings of Annoyance towards classroom noise were not associated with any executive function skills. This points again at the relative dissociation between the two sets of reactions to noise. Attention capture and Interference might reflect difficulties in maintaining and achieving goals in the presence of noise. However, Annoyance might reflect judgments and attitudes towards the situation. The perceived costs and benefits of the noise, emotional and social cues can all relate to feelings of annoyance (Stallen, 1999).

As such, results from Chapter 5 are congruent with those from Chapter 4: They suggest a partial distinction between reactions of Interference and of Annoyance. In particular, in Chapter 4, mind-wandering predicted noise Interference, not Annoyance. In Chapter 5, reaction time variability at the SART, and working memory, both thought to be related to mind-wandering, predict Interference, but not Annoyance. To close the loop, the direct

relations between switching skills and mind-wandering, on one side, and attention and working memory, on the other side, were tested.

Contrary to what was expected, reaction time variability in the SART was not related to mind-wandering. This is surprising, given consistent findings showing a positive correlation between reaction time variability and mind-wandering (Hu, He, & Xu, 2012; McVay & Kane, 2009; Seli, Cheyne, & Smilek, 2013; Zhang, Song, Ye, & Wang, 2015). However, all these studies embedded the mind-wandering measure *within* the task measuring reaction time variability. Mind-wandering episodes were therefore specific to that behavioural task. In contrast, the mind-wandering questionnaire used in the current study was broad, and was related to various situations in everyday life (reading, listening to a lesson). This looser approach might have reduced correlations with laboratory-based assessments of reaction time variability.

In line with adult findings (Hu et al., 2012), mind-wandering did not relate to inhibitory control as assessed with the Flanker task. Hu et al. (2012) suggested that mind-wandering might be associated with proactive control (the capacity to maintain goals in mind), rather than with reactive control (the capacity to resolve conflicts, as assessed in the Flanker task).

Furthermore, mind-wandering was not related to working memory capacity. Mrazek, Franklin et al. (2013) did find a correlation between their mind-wandering questionnaire and a working memory task, but these two measures were administered in immediate succession. Furthermore, thought probes were embedded *within* the working memory task, asking participants whether they were on-task, or mind-wandering. This might have led participants

to answer the subsequent mind-wandering questionnaire based on their levels of attention during the working memory task. Since the relation between working memory and mind-wandering in daily life depends on the level of challenge and effort demanded by the task (Kane et al., 2007), correlations might be more salient when mind-wandering is assessed in relation to demanding tasks involving working memory (also see Unsworth & McMillan, 2013).

Structural Equation Models relating mind-wandering propensity to sustained attention, as assessed by the Letter Cancellation Task, did not have good fit. This problem was not encountered in the models including the mind-wandering measure in Chapter 4, or relating mind-wandering with reaction time variability, inhibitory control, and working memory. Structural Equation Models rely on the analysis of the covariance matrix between *all* the variables in a given model. The poor fit of the models involving mind-wandering and the Letter Cancellation task could be related to the specific correlation between *one* item of the mind-wandering questionnaire and the Letter Cancellation task: the tendency to think about unrelated things during lessons was related to lower scores at the Letter Cancellation Task. This finding bridges a gap between survey and behavioural methodologies; namely, pupils' capacity to maintain their attention on an ongoing lesson (as they indicate it themselves in a questionnaire), was related to a laboratory-based assessment of sustained attention. However, the fact that this correlation was not consistent across all the mind-wandering items could have caused inconsistencies in the model. Furthermore, it is possible that this correlation might have emerged by chance from the multiple correlations being tested. Despite the prevalence of mind-wandering in classroom settings (Szpunar et al., 2013), the study of its underlying processes, especially in primary school populations, is still in its infancy.

The present results suggest methodological constraints in this endeavour, and new avenues for research.

The switching and mind-wandering questionnaires were correlated, but the present study did not identify a common underlying attentional mechanism. None of the Structural Equation models showed a relation between switching skills and behavioural assessments of attention and working memory. This was also the case when looking at the correlations calculated on individual items from the switching questionnaire. This finding is surprising, given theoretical and empirical models highlighting the relations between switching skills, attentional control and working memory (Diamond, 2013; Miyake et al., 2000; see Brydges et al., 2014; Lehto et al., 2003 for child studies). However, questionnaire, and behavioural measures of executive functions might not reflect similar constructs. The self-report questionnaire of switching skills reflected children’s behaviour in real-life settings, in various situations, over a two-weeks period. In contrast, the behavioural tests of attention and working memory assessed children’s behaviour in standardised conditions, with a very specific task, and over a short period of time. Measures were not made on the same level and may therefore tap into different cognitive processes – the self-report questionnaire being also influenced by children’s awareness of their mental processes.

5.3. Conclusion and future directions

Figure 5.3 summarises the main findings of the present study, along with those of Chapter 4.

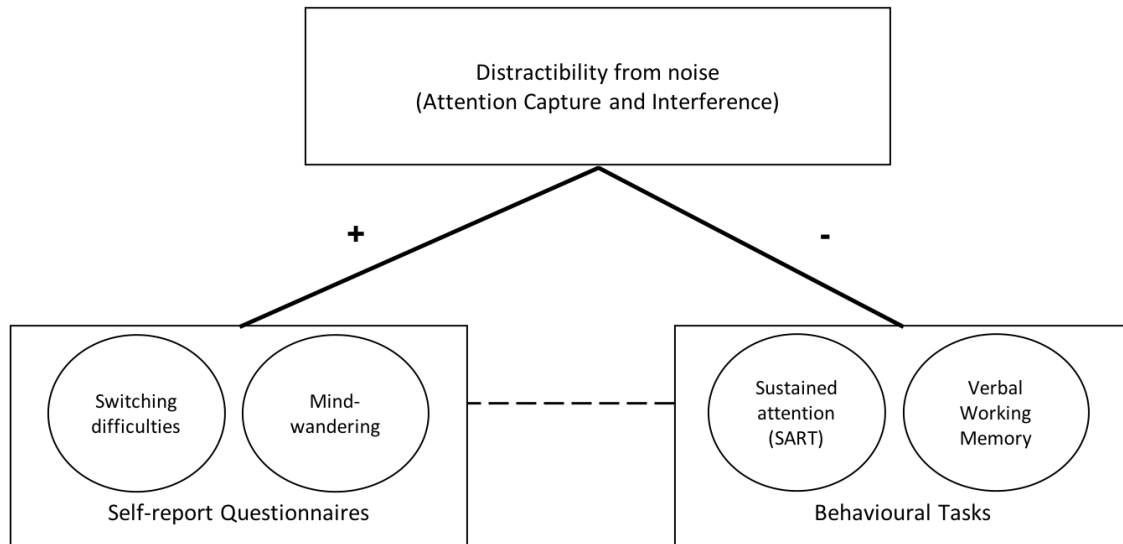


Figure 5.3. Summary of the findings from Chapters 4 and 5. Bold lines represent significant relations, dotted lines non-significant relations.

The present study showed that noticing noise, and feeling distracted by it in a classroom setting, were associated with lower sustained attention and working memory. These two skills might help children staying on task and keeping their goals in mind in the presence of noise. The results can be put in perspective with those of Chapters 2 and 3, showing that executive functions protected children against the negative effects of classroom noise when they were engaged in specific tasks.

In Chapter 2 better working memory was protective against the impact of classroom noise on a mathematics task. In Chapter 3, inhibitory control was protective against the impact of classroom noise on an idea generation task. These results suggest that it might be beneficial

to move to training studies, targeting the development of executive function skills. Indeed, testing whether improvements in children’s executive functions skills is associated with similar improvements in their school performance and reactions to noise would provide a more stringent test of causal relationships. Moving beyond correlation analyses, Chapters 6 and 7 will offer both longitudinal and intervention approaches, over a 6 months period, testing children before and after the implementation of in-class noise reduction programs.

Chapter 6 - Designing school-based interventions aiming to reduce
classroom noise

6.1. Chapter overview⁸

In the previous chapters, the effects of noise were investigated during one-shot assessments, using scores at behavioural tasks and surveys with predefined answers. The current chapter adopts a longitudinal approach, following children over a 6-months period, before and after the implementation of two types of interventions aimed at reducing classroom noise. These interventions consisted of: 1) mindfulness practice, 2) a sound awareness intervention.

Mindfulness practice has been shown to help children regulate their attention, emotion, behaviour, and to reduce classroom noise (Felver, Celis-de Hoyos, Tezanos, & Singh, 2016; Norlander, Moås, & Archer, 2005). Whether it impacts children's perception of noise has to be tested. Of crucial interest is to test whether changes in executive functions co-occur with changes in children's reactions to noise, and/or with changes in classroom noise levels.

Separately from the mindfulness practice, a sound awareness intervention was designed to help children become better aware of their auditory environment, and to regulate noise levels in the classroom. The intervention was specific to the issue of noise in class. It provided the opportunity to compare the effects of mindfulness practice with another type of active intervention, and to test whether they are underlined by the same mechanisms.

⁸ The work in this chapter is currently under review: Massonnié, J., Frassetto, P., Mareschal, D. & Kirkham, N. (under review). Doing science in collaboration with educators: Practical insights from an in-class noise reduction intervention.

To provide a more complete approach to the issue of classroom noise, pupils were here considered as not just “enduring” noise, but also as “generating” noise.

The present chapter focuses specifically on: 1) the implementation of the two types of interventions, and 2) children’s self-reported feelings and changes in mood and attention over the course of the interventions. It is based on questionnaire data, as indicated in Figure 6.1. The evolution of classroom noise levels, children’s reactions to noise, executive functions, and school performance, will be presented in Chapter 7.

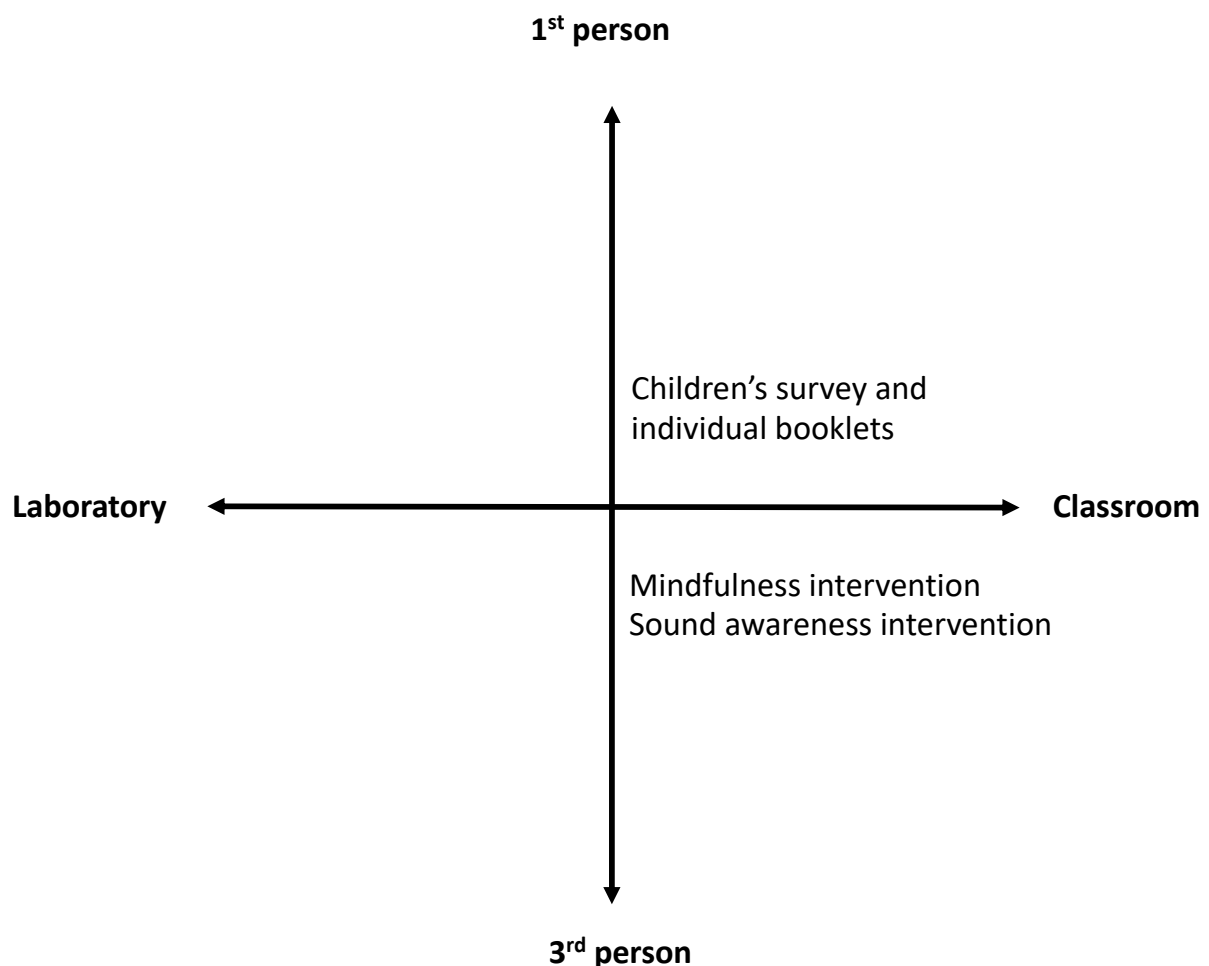


Figure 6.1. Methodological approach used in Chapter 6

6.2. Experiment 3: Designing school-based interventions aiming to reduce classroom noise

6.2.1. Introduction

Physical solutions to the issue of noise have been proposed in the literature. Sound absorbent panels, carpets or ceiling hangings can all absorb noise and reduce reverberation (Berg et al., 1996; Bronzaft, 1981; Cohen et al., 1981; Maxwell & Evans, 2000). This might be particularly useful when schools are exposed to high levels of external noise (e.g., road traffic noise, aircraft noise), and when it is difficult to meet the official requirement of 35dB of background noise in empty classrooms (Education Funding Agency, 2015). However, these physical solutions raise several issues.

First of all, they are expensive (estimated at up to thousands of pounds for a classroom), and they require the involvement of multiple stakeholders (not only the teachers and the school board, but also educational and administrative institutions at higher levels, particularly if funding resources are required). It might therefore be difficult, and slow, for teachers to implement them. Second, physical solutions to the issue of noise should not be considered in isolation, as acoustical comfort interacts with other environmental factors, such as thermal and lighting comfort (Montazami, Gaterell, & Nicol, 2015; Woolner & Hall, 2010). Montazami et al. (2015) give the example of carpets and ceiling hangings that collect dust and therefore reduce air quality. Third, and more fundamentally, aiming to reduce noise levels *in general*, without discriminating which type of noise, and when to regulate it, might not be an optimal educational solution.

Absorbent material can actually make it more difficult to perceive the teachers' voice (Berg et al., 1996), and whether noise is negative for learning and/or annoying should be understood in light of the specific educational context. As was shown in Chapters 2 and 3, although irrelevant noise might impair children's performance when they are engaged in attention and memory tasks (Klatte et al., 2013), moderate classroom noise does not necessarily have a negative impact on school performance (Dockrell & Shield, 2006; Ljung, Sörqvist, & Hygge, 2009). Furthermore, in comparison with solo work, where the main goal is to stay on task, noise might be less detrimental during collaborative activities, where one of the main purposes is to facilitate exchanges and discussions. Descriptive statistics from Chapter 4 (Table 4.1) suggested that children's levels of annoyance and distraction from noise is lower when they are engaged in group activities, compared to when they are engaged in solo work. Given these variations in the effects of noise, participatory approaches to tackle the issue of noise in schools can prove more flexible and empowering for teachers and children than physical solutions (Woolner & Hall, 2010). To promote a participatory approach, it is possible to use tools allowing children and teachers to regulate noise levels by themselves.

The use of visual monitors to display and control noise levels is recommended on educational and commercial websites (e.g. see the apps Bouncyballs or Too Noisy). They take the form of visual tools (e.g. a red signal), helping children to realise when noise levels are above a certain threshold. The concrete outcomes of such practices are unclear, and there is little scientific evidence backing them up. A commercial tool, SoundEar®, has been tested. This device takes the form of a human ear, with three different levels of lighting depending on whether noise levels are acceptable, close to a pre-set limit, or exceeding a pre-set limit. The target threshold

can be set up by the user, between 40 and 115dB, depending on the type of activity children are engaged in. An experimental study in three classrooms, from Grades 1 to 3, showed that a 6-day intervention with SoundEar® reduced noise levels of 1.4dB on average (Van Tonder, Woite, Strydom, Mahomed, & Swanepoel, 2015). However, tests of statistical significance were not provided, and it is unsure whether this 1.4dB improved the teachers' and students' subjective wellbeing. Furthermore, the device was introduced without any complementary instruction about sound, noise, and their effects on health. Enhanced instructions could favour a more efficient implementation of noise regulation activities (Daniel, 2007).

Bulunuz (2014) tested the impact of education seminars on the theme of noise delivered to primary school students (1- to 2-hours workshops) and teachers (2- to 3-hours workshops). They revealed paradoxical findings. First, although a higher percentage of teachers thought that noise pollution could be prevented after the workshop, there was no modification in the levels of noise in the schools - measures were taken in corridors and not in classes, which would give more information about the effects of noise on learning outcomes. Second, students reported *more* annoyance at noise after the intervention. It is possible that the program raised pupils' and teachers' awareness about noise, without providing efficient tools to regulate it. Combining an educational program with a system of visual aid (like SoundEar®), is promising as it combines the strength of both types of interventions while mitigating their weaknesses.

Sound awareness interventions would also provide a key opportunity to collect children's views as to what constitutes a noise in their classroom (e.g. which sounds are especially unpleasant). This would complement both the experimental, and survey-based approaches

used throughout this thesis. In Chapters 2 and 3, and in the experimental literature evaluating the impact of noise on task performance, noise stimuli were created by the experimenters, and presented as sounds that were irrelevant for the task participants had to perform (e.g. answering questions on a text while hearing a different story over headphones). In Chapters 4 and 5, and in studies using a survey methodology, the “noise” was left to be defined by the participants. It is unclear, for example, which situations the participants would think of when replying to questions such as: “How annoyed are you by classroom noise?”.

Since children can be annoyed by classroom noise (in Chapter 4, they reported an average degree of annoyance of 6.48/10), asking them in more details which sounds are pleasant or unpleasant might help to better identify which types of noise they think about when answering the surveys. This is important not only as a methodological issue, but also, more practically, to identify which sounds can build a positive or, in contrast, a negative environment for children. This would be a first step to regulate noise in the classroom. Such an approach is quite specifically raising discussions about the issue of noise.

Another approach that has been proposed to reduce noise levels focuses on relaxation practice, and highlights children’s general awareness of their body and of their environment. Norlander et al. (2005) reported a reduction of noise from 63.24dB to 50.50dB in primary and secondary classrooms, and better levels of concentration in the children (as indicated by their teacher) following a 4-week intervention program during which they practiced relaxation exercises twice a day. However, questionnaire data indicated no changes in pupils’ perception of noise and stress levels, probably because they did not consider their classrooms very noisy to start with (on a scale from 1 to 7, they gave a value of 3.38 before the intervention, and of

3 after the intervention). Furthermore, the study included five intervention groups (practicing relaxation), but only one control classroom, which had higher baseline levels of noise (72.91dB). A more balanced design, with matched groups, might provide a stronger evidence in favour of the relaxation training. Furthermore, although it is specified that the program “consisted of a combination of stretching exercises and relaxation exercises” (Norlander et al., 2005, p. 95), the exact content of the sessions was unclear.

Results from Norlander et al. (2005) are in line with the growing literature about yoga and mindfulness practice revealing beneficial impacts on children’s capacity to regulate their attention and behaviour, as well as their mood and emotions (Felver et al., 2016; Ferreira-Vorkapic et al., 2015; Rempel, 2012; Zenner, Herrnleben-Kurz, & Walach, 2014). Debates about the exact definition of, and overlap between relaxation, yoga and mindfulness are beyond the scope of this thesis. For the purpose of clarity, mindfulness will be defined as “the awareness that emerges through paying attention on purpose, in the present moment, and nonjudgmentally to the unfolding of experience moment by moment” (Kabat-Zinn, 2003, p. 145). Mindfulness includes elements of yoga, which itself involves different techniques such as physical postures, breathing exercises, relaxation and meditation (Ferreira-Vorkapic et al., 2015). However, mindfulness practice highlights the need to train one’s attention, and to adopt an open and accepting orientation toward one’s experience (Rempel, 2012).

Despite the promising benefits of yoga and mindfulness, none of the studies reviewed measured noise levels in the classroom, as was the case in the relaxation study from Norlander et al. (2005), and few of the measures used tapped into children’s perception of their auditory environment. As with the educational workshops about sound and noise

(Bulunuz, 2014), raising children's awareness about their sensory experience could make the noise more salient to them. However, the non-judgemental aspect of mindfulness practice could prevent the emergence of annoyance feelings. New studies are needed to shed light on these questions, and to strengthen the current research on yoga and mindfulness. The use of experimental designs with both active and "business as usual" control groups, the inclusion of observational and self-report measures, and the collection of follow-up data are especially recommended (Chung, 2018; Felver et al., 2016; Ferreira-Vorkapic et al., 2015; Zenner et al., 2014).

6.2.2. Aims of the current investigation

The current chapter presents the development of two types of interventions addressing these needs. The first one combines yoga and mindfulness exercises, designed to raise children's awareness about their body, their senses and their environment. This intervention adopts a broad approach, focusing on the regulation of attention, emotions and thoughts, and is not specific to the perception of noise and sound – reducing mindfulness practice to this aspect would be at odds with the current literature. The second type of intervention focuses on sound and noise. It combines the use of a visual system, to help children become aware of noise levels in their classroom, with workshops introducing the children to the core concepts of sound and noise, along with their effects on health.

This chapter describes how the interventions were created in collaboration with artists, teachers and practitioners, and provides data on the fidelity of their implementation. Children's feedback, their self-reported feelings and changes in attention and mood as the

interventions were happening are analysed. In line with the current literature, it was hypothesized that mindfulness practice would be associated with improvements in attention and mood (Felver et al., 2016; Zenner et al., 2014). Given the novel aspect of the sound awareness workshops, and the paradoxical findings reported by Bulunuz (2014), it was unclear whether these would also improve children's mood and attention, have a neutral, or a negative impact.

The next Chapter tests whether the interventions had an impact on classroom noise levels, children's reactions to noise, performance on behavioural tests of attention and, ultimately, on their school performance. Before detailing this whole set of analyses, it is important to fully describe and understand the activities children were engaged in.

6.2.3. Methods

6.2.3.1. Design of the interventions

The school interventions had a *short-term* and a *long-term* dimension. All the children participated in both dimensions. During the *short-term* part, children followed four hours of workshops (either on mindfulness, or on sound awareness), spread over a maximum of two weeks. Because the workshops required specific knowledge, materials and attitude, external experts were recruited to deliver them. This also reduced biases related to teaching style. Each expert delivered the same intervention in two classes. The *long-term* dimension of the interventions was led by teachers. They were provided with materials that they could use with their pupils on a daily basis, for 5 to 10 minutes, over a period of 10 weeks. The

interventions fit with the school curriculum in France (where the study was carried out) and allowed teachers to work on core skills and elements of knowledge (e.g. science and technology, musical education, discussion of feelings and emotions). Directly involving teachers allowed to test the generalisability of the interventions (e.g. not all schools have the budget to hire external experts, and these are not always available), while taking each school's context and needs into account (Coe, 2017; Kelleher & Whitman, 2018).

The length of the interventions was determined by combining the available scientific evidence and the practical constraints teachers faced in their daily schedule. With regards to the sound awareness workshops, the short-term intervention allowed for direct comparison with Bulunuz (2014)'s study, which tested the impact of 1- to 3-hours seminars about noise in schools. More long-term assessments are also necessary because students and teachers might need time to implement new attitudes (Bulunuz, 2014; Van Tonder et al., 2015). With regards to the mindfulness workshops, there is a great deal of variability in the literature surrounding the total number of sessions used, their length, frequency, and spacing (Felter et al., 2016; Zenner et al., 2014). As was the case during the short-term interventions of the current study, long sessions are more likely to be carried out by external facilitators (Felter et al., 2016). The long-term intervention implements the minimum amount of daily practice that has been used in the literature (5 to 10 minutes), which fits with the duration of the relaxation sessions implemented by Norlander et al. (2005) – although in their study, the activities were done twice a day, and not only once.

6.2.3.2. Mindfulness intervention

The short-term intervention

The mindfulness workshops were designed in collaboration with Marie Frassetto, who co-founded the association Kid Yoga, (<http://kidyoga.fr/yoga-tutorials.html>) and had six years of experience conducting classes with children. The workshops included a combination of body postures, breathing, meditation, and sensory awareness activities, with the overall aim of adopting a non-judgemental attention to the present-moment experience, in line with Kabat-Zinn (2003)'s definition of mindfulness. Information was given to pupils about the different muscles and components of their body, along with basic mechanisms of attention, in order for them to better understand the purpose of the activities. During the practice, children were alternating between standing and seating positions (see Figure 6.2), and were invited to make as little noise as possible when doing so. More details about the content of each session is available in Appendix F.



Figure 6.2. Pictures from the mindfulness workshops, including body postures (left) and meditation (right)

The long-term intervention

Four sound files were created by Marie Frassetto, corresponding to the four meditations used during the short-term intervention. Each sound file lasted between 2:53 and 4:41 minutes. Teachers were instructed to use one sound file a day. Since the school week was composed of four days, the four files were then used across the week. The recommended moment for the meditation practice was after the lunch break. This followed from conversations with teachers, who considered it to be one of the noisiest moments of the day. If it was in conflict with other activities during that time of the day, teachers were encouraged to do the practice at another moment, instead of cancelling it. After each meditation practice, children were invited to fill an individual booklet, reporting the date, time of the day, sound file used, and several measures of mood and attention that will be further described in section 6.2.3.7.

6.2.3.3. Sound awareness intervention

The short-term intervention

The sound awareness workshops were created with the sound artist Tommy Lawson and included hands-on activities to understand the relative differences between sound, noise and music. Children were invited to pay attention to, and to describe the sounds they could hear inside and outside the classroom. This introduced the notion of a *soundscape*, which describes the variety of sounds composing a specific environment. The main characteristics of sounds (timbre, pitch, length, loudness) were presented and discussed by the mean of interactive material. Using tablets, children were provided with a “bank” of sounds they could manipulate according to each characteristic (see pictures in Figure 6.3). For the purposes of

the workshop, noises were defined as sounds that are unpleasant or difficult to recognize and classify. Different sounds that are particularly present in the school environment (e.g. a door slamming, the bell ringing, the noise coming from chairs scrapping the floor) were presented. Children discussed whether they perceived them as pleasant or unpleasant and, as the expert increased their loudness, he raised awareness of the increasing level of stress and increasing difficulties to communicate. The measurement of noise levels with sound level meters was introduced, along with typical noise levels generated by different everyday activities (in decibels). Information about the auditory system was presented in order to raise awareness of the harmful effects of high noise levels. The impact of noise on attention, memory, and other people's wellbeing was also discussed. Visual panels with in-built microphones, to be used during the long-term intervention, were introduced. They lit up with different colours, depending on the current level of noise. Green indicated a calm atmosphere ($< 50\text{dB}$), orange moderate noise levels ($50\text{-}70\text{dB}$), and red high noise levels ($> 70\text{dB}$). When the classroom was calm for more than few seconds and when there were no more fluctuations in noise levels (no sound standing out from the context), the panels went black. Children were invited to use the visual panels as a reminder to pay attention to noise, and as a prompt to make less noise when the lights turned red.



Figure 6.3. Pictures from the sound awareness workshops, including the manipulation of sounds (left), and the presentation of the visual panels (right)

The long-term intervention

A combination of daily and weekly activities was designed. The daily activity consisted in children playing the “silence game”. They had to control noise levels, so that the panels became black, and to hold this silence for as long as possible (up to three minutes). The recommended time of practice was after the lunch break, as for the mindfulness intervention. The game was piloted during the short-term intervention, and proved to be both challenging and fun for children. However, there was a risk that children would become very good at it and would then spend only a few seconds or minutes being engaged in the activity. The weekly activities were therefore provided as a complement and focused on the perception of sound and noise. A list of 10 activities was given (one per week). Children had to engage in the activity (e.g. everyone talking at the same time), and to individually estimate the amount of noise (in decibels) it generated. Then, children collectively checked the actual level of noise using a handheld sound level meter (Tacklife Professional Sound Level Meter SLM01, 40-130dB). The main goal of this activity was for children to further explore the range of noise levels that can be generated in the classroom. The full list of activities is provided in Appendix G. Children were provided with an individual booklet which contained two parts: one for the daily activities (reporting the duration of the silence game, and self-report measures of mood and attention); one for the weekly activities (reporting estimated and actual noise levels generated by the different activities). Each time they filled their booklets, children reported the date and time of the day.

6.2.3.4. Fidelity

A great challenge faced when designing the school interventions includes their fidelity, which can be assessed according to five dimensions: adherence (i.e. the extent to which the implementation is consistent with the way the program was written), dose (i.e. the amount of program delivered), the quality of program delivery (i.e. whether the provider approached a predefined “ideal” when delivering the program content), participants responsiveness (i.e. their engagement and involvement with the program) and program differentiation (i.e. the critical features distinguishing the program from other alternatives; Dusenbury, Brannigan, Falco, & Hansen, 2003).

In the short-term intervention, the same expert led the same workshop in two different classrooms, following the same sequence of four hours. This way, adherence was optimised, and the dose and quality of program delivery were controlled for. It was also important to make sure that teachers were not varying massively in the way they implemented the long-term interventions. Children’s booklets helped to keep track of what happened in classrooms, including when and at which frequency they practiced the activities, without putting pressure on the teachers to report themselves what happened every day. Adherence was maximised by providing teachers with a restricted range of activities to perform; however, the quality of program delivery could not be assessed on a daily basis. To assess participants responsiveness, questionnaires were filled by children each time they were engaged in the daily activity, and at the end of both the short-term and the long-term interventions. Finally, the detailed description of the interventions highlights the key components that might be differentiated from other alternatives (i.e. program differentiation).

6.2.3.5. Participants

Children were recruited from the same six French primary classrooms than in Chapters 4 and 5, in Corsica, France. The six classrooms comprised 134 children in total, at the start of the study. Parental consent was obtained for 121 pupils. Eight were in CE2 (Year 4 in the UK), fifty-two in CM1 (Year 5) and sixty-one in CM2 (Year 6). The following exclusion criterion were then applied: 1) Data from Year 4 pupils were excluded for the purpose of homogeneity ($n = 8$); 2) Data from one child, for whom hearing disorders were reported by the parents, were removed; 3) Data from three children who changed school during the intervention study, were also excluded. Note that this last criterion was not applied in Chapters 4 and 5, which focused on data collected before the start of the interventions. The final sample included 109 children, from 8.70 to 11.38 years of age ($M = 10.03$; $SD = .60$; see Figure 6.4 for a summary).

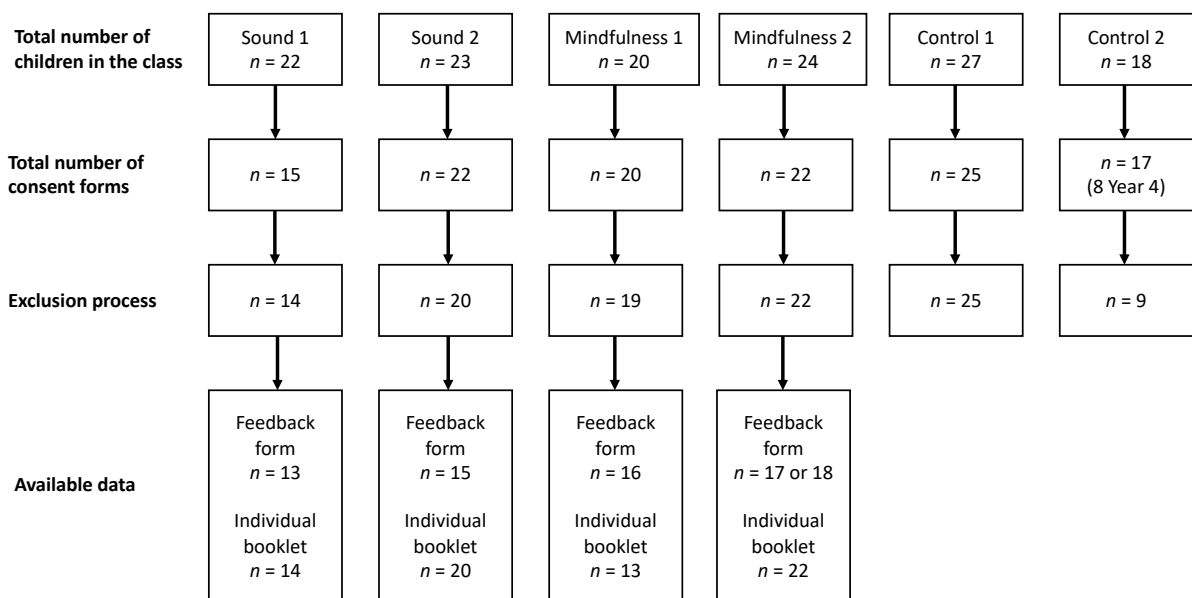


Figure 6.4. Diagram summarising the data available for each participating class

The six classes were assigned to one of three intervention groups (mindfulness, sound awareness, waiting-list control) in a pseudo-random way (see Table 6.1). This was done to balance the age of children across groups and to avoid school effects. In fact, the six classes were recruited from four schools, meaning that two schools provided two classes each. Assigning the two classes from the same school to the same condition (e.g. mindfulness), and the two classes to another (e.g. sound awareness) would have confounded the effect of the school with that of the condition. It should however be kept in mind that the chosen procedure (assigning classes from the same school to different conditions) raised the risk of diffusion effects – children from different intervention groups influencing each other. To minimize this, teachers were asked not to share their material with each other until the study was finished. All the schools were bilingual, that is to say, children were exposed to both French (the national language) and Corsican (the regional language). The present chapter focuses on data from the mindfulness and sound awareness groups.

Table 6.1. Assignment procedure

Class	School	Age Group(s)
Sound 1	School A	Year 6
Sound 2	School B	Year 5 / Year 6
Mindfulness 1	School A	Year 5
Mindfulness 2	School C	Year 6
Control 1	School C	Year 5 / Year 6
Control 2	School D	Year 5 / Year 6

The project received ethical approval from the University’s Departmental Ethics Committee, as well as from the French educational inspector who was in charge of supervising the six participating classes. The interventions were integrated in the school curriculum and all the children took part, following an opt-out procedure. However, individual data were collected following an opt-in procedure. All the participants gave verbal consent, and written informed consent was obtained from their guardian. The study was conducted in accordance with the Declaration of Helsinki.

6.2.3.6. Procedure

The study started in January, 2018, and the full timeline is presented in Figure 6.5.

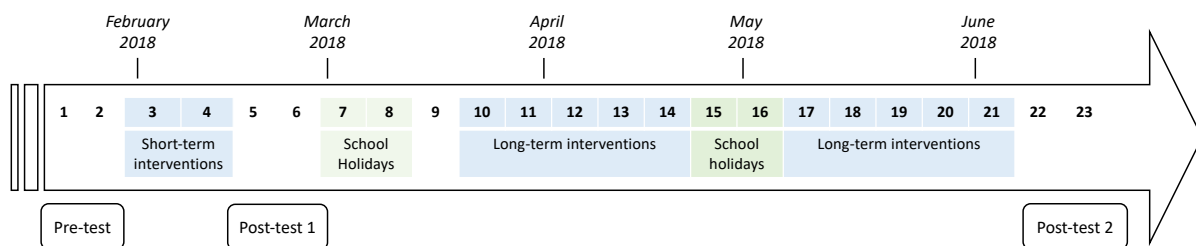


Figure 6.5. Timeline of the project. Bold numbers are week numbers.

A Pre-test session was organised in January, 2018. The short-term interventions were then organised, followed by the first post-test (Post-test 1), after which children went on holidays. The long-term interventions started one week after children got back from holidays – this allowed time for teachers to get used to the intervention materials, and to get back to their usual teaching “routine” following the two-weeks break. The long-term interventions were then implemented for five weeks in a row. After a two-weeks interruption due to additional school holidays, the activities were carried out for another five weeks, followed by a second

post-test (Post-test 2). The same battery of test was used at the three testing points (Pre-test, Post-test 1, Post-test 2). Children were tested individually on a Letter Cancellation Task (measuring sustained attention), Flanker task (inhibitory control) and Sustained Attention to Response Task (measuring both sustained attention and response inhibition). Collective sessions included assessments of Working Memory, Reading Comprehension and Mathematics, as well as a questionnaire about children's reactions to noise. Some of the pre-test data were presented in Chapters 4 and 5. The present chapter focuses on children's feedback about the interventions, collected during the two post-tests, as well as on data collected from the booklets children used during the long-term interventions.

6.2.3.7. Measures

Children's feedback about the interventions was assessed by three questions at the end of the short-term (Post-test 1) and long-term (Post-test 2) interventions: Did you like the activities? Did you find the activities difficult? Did you find the activities useful? Children answered on a 4-points scale ("Not at all"; "Not really"; "A bit"; "Really"). An open question invited children to share any comment they had on the activities. At Post-test 2, a more specific open question was also added: "Do you think the activities changed the atmosphere in the classroom? If so, how?".

Individual booklets

Mindfulness group. Each page of the booklet corresponded to a day of practice (see Figure 6.6, left panel). On the top of each page, children indicated the date, time, and sound file used for the meditation practice. They were then asked four questions. First, they were

provided with a word cloud, and had to select the word that best described how they felt after the practice. There were 21 words: 7 described a neutral attitude (e.g. “neutral”, “normal”); 7 described an attitude that is often considered desirable in school settings (e.g. “focused”, “calm”); 7 described an attitude that is often considered undesirable (e.g. “distracted”, “agitated”). The positive and negative adjectives were selected to mirror each other (e.g. “focused” vs “distracted”). The position of the words was randomised across the different days. The definition of each word was written in a glossary, printed at the end of the booklet. Following the word cloud, children were asked in which way their attention evolved following the activity, compared to when they arrived in the classroom before the activity. They provided their answer on a 5-points scale (“Way less attentive”, “A little less attentive”, “Similar”, “A bit more attentive”, “Way more attentive”). These answers were recoded with the following values: -2, -1, 0, 1, 2. The third question focused on how their mood evolved following the activity, compared to when they arrived in the classroom before the activity. Children gave their answer on a 5-points scale (“Far less well”, “Somewhat less well”, “Similar”, “A bit better”, “Way better”). Again, the answers were recoded: -2, -1, 0, 1, 2. Finally, children were asked whether they used a meditation technique since the last session in class, and if so, when and for which purpose.

Sound awareness group. The booklet for the sound awareness group comprised two parts: one for the daily activities (see Figure 6.6, right panel), one for the weekly activities. For each activity, children reported the date and time. For the daily activity, the “silence game”, they wrote down how long the classroom managed to stay silent (the actual value being timed by the teacher). Then, the same three questions as in the mindfulness booklet were provided: children selected the word that best described how they felt after the practice, and indicated the evolution of their mood and attention. Finally, they were asked to

report what was the most pleasant, and the most unpleasant sound they heard in the morning. For the weekly activities, children reported which classroom activity (from the list of 10) they were engaged in, their estimate of noise levels generated by the activity (in decibels), and the actual noise levels recorded by the sound level meter.

For each condition, the first pages of the booklets contained an introduction about the long-term intervention, and an explanation of the different measures, with example items. On the first day of the long-term interventions, children went through these pages with their teacher to make sure that they understood the process.

Left Page (Mindfulness):

Date : _____
 Heure : _____
 Bande audio utilisée : _____

Entoure le mot qui décrit le mieux comment tu te sens juste après l'activité :

Par rapport au moment où tu es entré dans la classe avant l'activité, comment a évolué ton attention ? Tu te sens ...

☐ Beaucoup moins attentif ☐ Un peu moins attentif ☐ Pareil(le) ☐ Un peu plus attentif ☐ Beaucoup plus attentif

Par rapport au moment où tu es entré dans la classe avant l'activité, comment a évolué ton humeur ? Tu te sens ...

☐ Beaucoup moins bien ☐ Un peu moins bien ☐ Pareil(le) ☐ Un peu mieux ☐ Beaucoup mieux

As-tu utilisé une technique de méditation (dans la classe ou en dehors), depuis la dernière séance en classe ? Si oui, quand et dans quel but ?

Right Page (Sound Awareness):

Date : _____
 Heure : _____

Le jeu du silence
 Combien de temps la classe a-t-elle tenue ? _____

Entoure le mot qui décrit le mieux comment tu te sens juste après l'activité :

Par rapport au moment où tu es entré dans la classe avant l'activité, comment a évolué ton attention ? Tu te sens ...

☐ Beaucoup moins attentif ☐ Un peu moins attentif ☐ Pareil(le) ☐ Un peu plus attentif ☐ Beaucoup plus attentif

Par rapport au moment où tu es entré dans la classe avant l'activité, comment a évolué ton humeur ? Tu te sens ...

☐ Beaucoup moins bien ☐ Un peu moins bien ☐ Pareil(le) ☐ Un peu mieux ☐ Beaucoup mieux

Quel est le son le plus agréable que tu aies entendu aujourd'hui ?

Quel est le son le plus désagréable que tu aies entendu aujourd'hui ?

Figure 6.6. Daily activities for the mindfulness (left) and sound awareness interventions (right)

6.2.4. Results

6.2.4.1. Implementation of the long-term interventions

The four classes varied in the way they implemented the interventions (see Table 6.2 for full details). Within each intervention group, one class practiced more than the other (the class Sound 1 practiced 12 days on average compared to 30 days for the class Sound 2; the class Mindfulness 2 practiced 16 days compared to 26 days for the class Mindfulness 1).

Within each class, the total number of days of practice varied from one child to another due to occasional absences. In line with the recommendations, the activities were mostly carried out after the lunch break, and occasionally after the morning or afternoon breaks. In the mindfulness condition, the four sound files were used an equivalent number of times, and mostly following a regular order (e.g. a given sound file was assigned to a given day of the week). Fourteen children (out of the 35 who took part in the mindfulness intervention) reported practicing (between one, and ten times) outside of the class. They mentioned using mindfulness to sleep better, to concentrate, and to calm down and relax, especially if they felt angry or stressed. Three children reported practicing with their family.

Table 6.2. Amount of practice (in days) for each class participating in the interventions

Class	Min	Max	<i>M</i>	<i>SD</i>
Sound 1	9	13	12.21	1.31
Sound 2	24	33	30.1	2.81
Mindfulness 1	21	29	25.85	2.38
Mindfulness 2	13	18	16.32	1.22

6.2.4.2. Children's feedback about the interventions

For each measure, only the data from children who answered both post-test questionnaires were analysed. This was to make sure that any difference between the results of Post-test 1 and Post-test 2 was not driven by a difference in the sample used. The amount of data available for each class is provided in Figure 6.4.

Mindfulness intervention

Children's feedback is reported in Table 6.3. Chi-Square tests of homogeneity did not reveal any significant differences between the two participating classes, whose results were therefore collapsed together. Friedman tests revealed that children preferred the short-term activities (94% rated them positively⁹) over the long-term activities (74% rated them positively; $\chi^2(1) = 8, p = .005$). They also found them more useful (82% vs 59% rated them

⁹ These percentages were calculated by collapsing the two "positive" answers (e.g. really liked the activities or liked them a bit) and the two "negative" answers (e.g. did not really like them, or not at all).

useful; $\chi^2(1) = 5.56, p = .018$). Few children found the activities difficult, and there was no significant difference between the short-term (12% rated as difficult) and the long-term (6% rated as difficult) components of the interventions ($\chi^2(1) = 3, p = .083$).

Table 6.3. Children’s feedback about the mindfulness interventions, for the two participating classes

	Mindfulness 1				Mindfulness 2				χ^2
	Not at all	Not really	A bit	Really	Not at all	Not really	A bit	Really	
<i>Short-term</i>									
Did you...									
... like the activities?	0	1	2	13	0	1	7	10	3.06
... find them difficult?	7	6	2	1	8	5	4	0	1.80
... find them useful?	0	2	5	9	1	3	7	7	1.67
<i>Long-term</i>									
Did you...									
... like the activities?	0	2	5	9	3	4	4	7	3.92
... find them difficult?	11	2	3	0	11	5	1	0	2.26
... find them useful?	2	5	2	7	3	4	7	4	3.80

When invited to share comments in an open-ended question, the majority of children (53% at Post-test 1, 71% at Post-test 2) did not leave any comment. When they did report comments, children wrote that the activities were great, fun, that they made them feel calmer, more relaxed, focused and peaceful (e.g.: “After [the] exercise, I was feeling calmer,

pacified. Thank you very much, I loved it”). Two children reported feeling tired, or feeling pain in their body after some sessions. When asked whether the long-term activities changed the atmosphere in class, 59% of the children said that this was not the case, and 15% did not write anything. The rest of the children reported a positive evolution, the class being calmer, more focused and less noisy (e.g.: *“Listening to what the lady was saying [on the sound files] helped me to concentrate and feel calmer. Since everyone was listening, it changed the atmosphere in class”).*

Sound awareness intervention

Children’s feedback is reported in Table 6.4. Chi-Square tests of homogeneity revealed only one difference between the two participating classes (see the χ^2 column in Table 6.4), and it was related to how much the children liked the activities. One class (Sound 1) reported more enthusiasm for the short-term intervention than the other (Sound 2). In Sound 1, *all* the children reported that they *really* liked the interventions; in Sound 2, the vast majority of the pupils still liked the interventions, but their answers were more nuanced, and one child did not really like them. The difference between the two classes was not significant when considering whether they liked the long-term intervention. This is because the overall enthusiasm previously noted in the class Sound 1 dropped a little bit, as shown by a Friedman test ($\chi^2(1) = 6, p = .014$).

Overall the majority of the children found the activities useful (82%¹⁰ for both the short-term and long-term components; $\chi^2(1) = .82, p = .37$). Only a few children found them

¹⁰ Again, this percentage was calculated by collapsing the two “positive” answers (e.g. found the activities a bit or really useful) and the two “negative” answers (e.g. did not really find them useful, or not at all). The distribution between the four possible answers was not exactly the same for the classes Sound 1 and Sound 2.

difficult (14% for the short-term component, 18% for the long-term component; $\chi^2(1) = .69$, $p = .41$).

Table 6.4. Children’s feedback about the sound awareness workshops, for the two participating classes

	Sound 1				Sound 2				χ^2
	Not	Not	A	Really	Not	Not	A	Really	
	at all	really	bit		at all	really	bit		
<i>Short-term</i>									
Did you...									
... like the activities?	0	0	0	13	0	1	6	8	8.09*
... find them difficult?	10	1	2	0	8	5	2	0	2.76
... find them useful?	1	0	5	7	1	3	6	5	3.30
<i>Long-term</i>									
Did you...									
... like the activities?	0	2	4	7	0	1	3	11	1.23
... find them difficult?	11	2	0	0	11	2	2	0	1.87
... find them useful?	1	1	6	5	1	2	7	5	0.27

* $p < .05$

When invited to comment openly on the activities, some children did not make any remark (36% at Post-test 1, 57% at Post-test 2). Most of the comments that were collected were positive: children reported that the interventions were great, and that they learned things (e.g. “It was great. It made me progress. Before, I was not listening much, now, I do”).

However, some children (one at Post-test 1, two at Post-test 2) enquired about the purpose of the activities. When asked whether the long-term activities changed the atmosphere in class, 50% of the children said that this was not the case, but the other half said that it had changed the atmosphere. They wrote that the class was quieter (e.g. *“Since the class did these activities, it is quieter”*).

Comparing the two intervention groups

Given the lack of significant difference between the two classes participating in each intervention (with one exception), children’s answers were then collapsed across classes within a same condition. Chi-square tests of homogeneity were performed to test for any potential difference between the mindfulness and sound awareness groups. Children did not differ in the extent to which they liked the activities ($\chi^2_{\text{SHORT}}(1) = .45, p = .80$; $\chi^2_{\text{LONG}}(1) = 3.82, p = .28$), found them useful ($\chi^2_{\text{SHORT}}(1) = .88, p = .83$; $\chi^2_{\text{LONG}}(1) = 4.52, p = .21$) or difficult ($\chi^2_{\text{SHORT}}(1) = 2.75, p = .43$; $\chi^2_{\text{LONG}}(1) = 1.08, p = .58$). Overall, participants were responsive, and the level of difficulty of the interventions was adapted.

6.2.4.3. Children’s individual booklets

Given the variability in the number of sessions carried out by the four participating classes (see Table 6.2), the analyses focus on the data from the first thirteen days of practice. This corresponds to the lowest common denominator – it is the highest number of available sessions for the children in the class Sound 1, which practiced the least.

Data from the individual booklets were available for all the children of the sample, with the exception of one class (Mindfulness 1), for which only 13 booklets (out of 19) were

returned to the research team. However, the six children for which the booklet data were unavailable did fill in the feedback form after the short-term interventions, and they did not differ from the others when considering whether they liked the interventions ($\chi^2(1) = 1.64, p = .44$), found them useful ($\chi^2(1) = 3.46, p = .33$) or difficult ($\chi^2(1) = .72, p = .70$).

Children's feeling after the practice, and their self-reported changes in mood and attention will first be analysed, based on the data available for both the mindfulness and sound awareness groups. The data specifically collected in the sound awareness group will then be described in further details, in order to have a better understanding of children's apprehension of their sound environment.

Children's feeling after the practice

Wordclouds were created to visually represent which adjective children selected to describe their feeling after the practice. The three most frequent words children used for the sound awareness practice were "normal", "tranquil" and "as usual" (corresponding to 39.15% of the answers). The three most frequent words children used for the mindfulness practice were "calm", "tranquil" and "normal" (corresponding to 41.98% of the answers). Overall, positive words were more frequent (45.48% in the sound awareness group, 53.85% in the mindfulness group) than neutral (33.49% and 26.15%) or negative words (17.19%, 17.80%). There were only 3% of missing data for this variable. The difference in distribution between the three types of adjective was significant for both the sound awareness ($\chi^2(2) = 55.57, p < .001$) and the mindfulness group ($\chi^2(2) = 97.40, p < .001$).

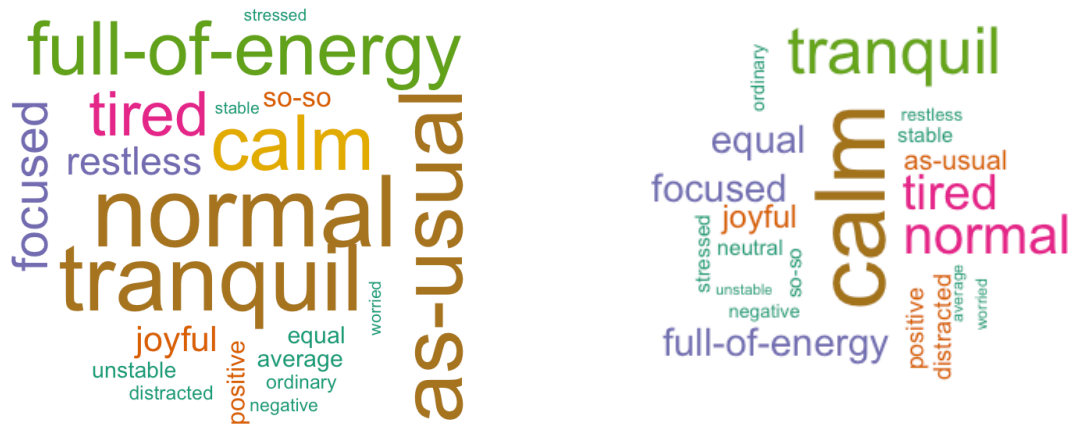


Figure 6.7. Wordclouds representing the adjective children selected to describe their feelings after the sound awareness (left panel) and the mindfulness (right panel) daily practice. A bigger font corresponds to a bigger frequency, and words that were reported a similar amount of time are depicted in the same colour.

Evolution of attention and mood

The evolution of attention and mood was analysed with Linear Mixed-Effects models, using RStudio (Version 1.1.453) and the *lme4* package (Bates, Mächler, Bolker, & Walker, 2015) set up to use full maximum-likelihood estimations.

It should be noted that 3.07% of the data points were missing. Little's Test (Little, 1988) indicated that the data were *not* completely missing at random ($\chi^2(291) = 425.14, p < .001$). However, it is unlikely that the pattern of missing data was related to the actual value reported by participants, in the sense that children who would be less attentive after the practice would not report it. As stated before, the booklets were filled in during collective sessions, under the supervision of the teacher, so each child who was present answered. Therefore, data could be considered missing *at random* (Graham, 2009). Although the *lme4* package deletes any uncomplete observation, mixed model estimation is robust to missing

data, especially since it corresponds to less than 5% of the observations (Field, Miles, & Field, 2012; Graham, 2009).

Four models were compared using likelihood ratio tests, each adding a single parameter to estimate the data. First, a model only including the fixed effect of Time (from Day 1 to Day 13) was compared to an empty model which only included an intercept. Second, a fixed-effect of Intervention Group (mindfulness vs sound awareness) was added on top of the effect of Time (without taking into account their potential interaction), and compared with the model only including the effect of Time. Third, the interaction between Intervention Group and Time was tested and compared to the additive model. Each model included a random intercept by subject, to take into account the fact that observations were nested within subjects. When fixed effects were identified, a random slope by individual was added. Specifying that children were nested within classes resulted in models that were too complex and did not converge. This is likely due to the fact that only two classes were participating in each intervention: once the effects of intervention group, and the random estimates between individuals were computed, it proved difficult to add additional estimates per class.

Evolution of attention

The model including a fixed effect of Time had better fit than the null model ($\chi^2(1) = 13.56, p < .001$). Model fit was not improved by adding the effect of Intervention Group ($\chi^2(1) = .28, p = .597$), or the interaction between Time and Intervention Group ($\chi^2(1) = .01, p = .932$). The model which only included the effect of Time was therefore selected. Adding a random slope by individual further improved model fit ($\chi^2(2) = 37.47, p < .001$). As shown by Figure 6.8, children reported an overall improvement in their attention following their daily practice - the line of best fit for the model was above zero, a value corresponding to no change in

attention (“Similar”). However, the improvement in attention diminished over time, as indicated by the negative slope ($\beta = -.023$). A closer look at the individual estimates showed that 70% of the children did have a negative slope. Some children, however, had a flat line or a positive slope. Furthermore, individual plots showing the evolution of attention for each child revealed different trajectories. Two examples are given in Figure 6.9. Whereas some children were quite constant in their answers, other reported greater fluctuations in the evolution of their attention depending on the day of practice.

How did your attention evolve, compared to the moment you arrived in class, before the practice? You feel...

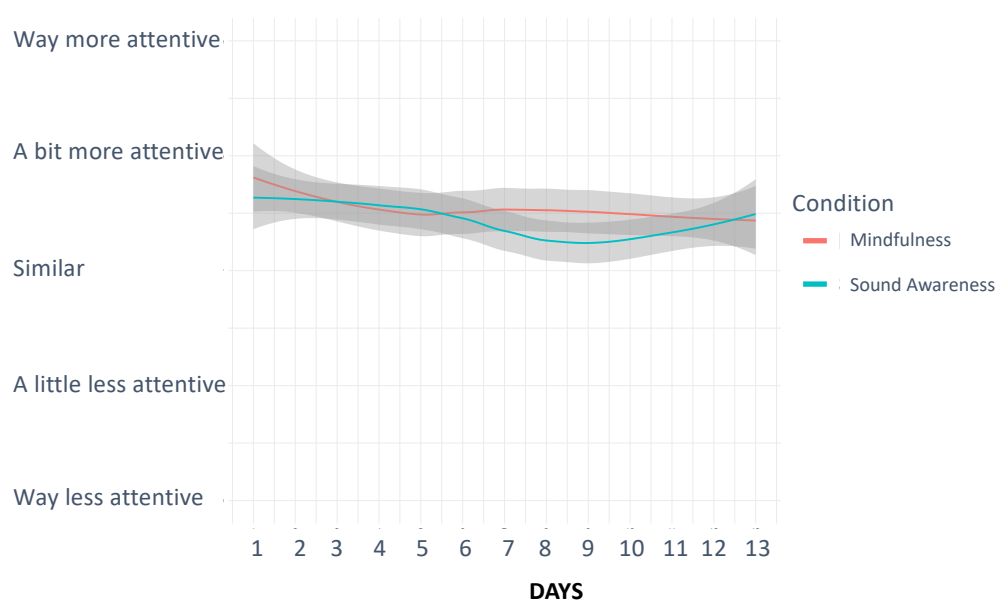


Figure 6.8. Evolution of children’s attention after the practice, for each intervention group, over the first 13 days of the long-term intervention. The grey shading represents the 95% confidence interval around the estimate.

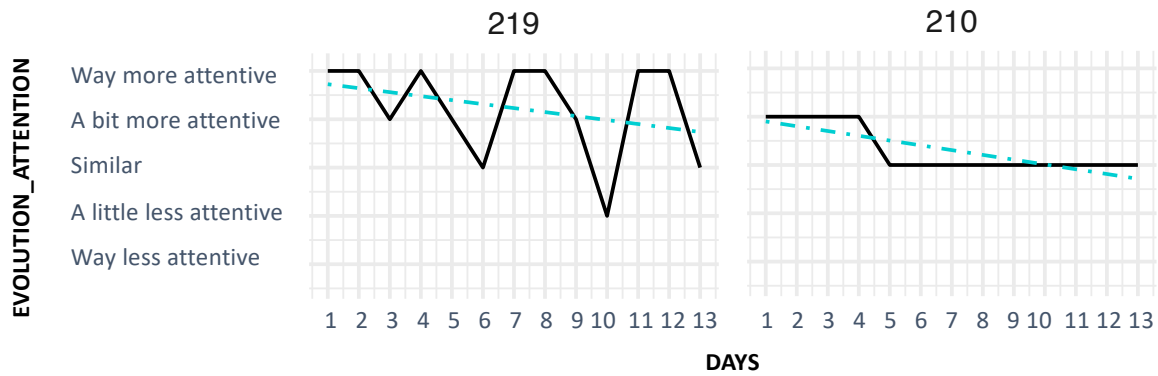


Figure 6.9. Two examples of individual trajectories when analysing the evolution of children's attention after the practice, over the first 13 days of the long-term intervention.

Evolution of mood

When considering the evolution of mood, a model including the fixed effect of Time did not prove to be better than a null model ($\chi^2(1) = 2.43, p = .119$). Taking into account the additive effect of Time and Intervention also did not improve the model's fit ($\chi^2(1) = .96, p = .328$). However, their interaction was significant ($\chi^2(1) = 4.12, p = .042$). Models were then run independently for the sound awareness, and the mindfulness groups. As shown in Figure 6.10, the (negative) effect of Time was significant for the sound awareness group ($\chi^2(1) = 8.51, \beta = -.024; p = .003$), but not for the mindfulness group ($\chi^2(1) = .055, p = .814$). Adding a random slope per individual (in the sound awareness group) did not further improve model fit ($\chi^2(2) = .74, p = .692$).

How did your mood evolve, compared to the moment you arrived in class, before the practice? You feel...

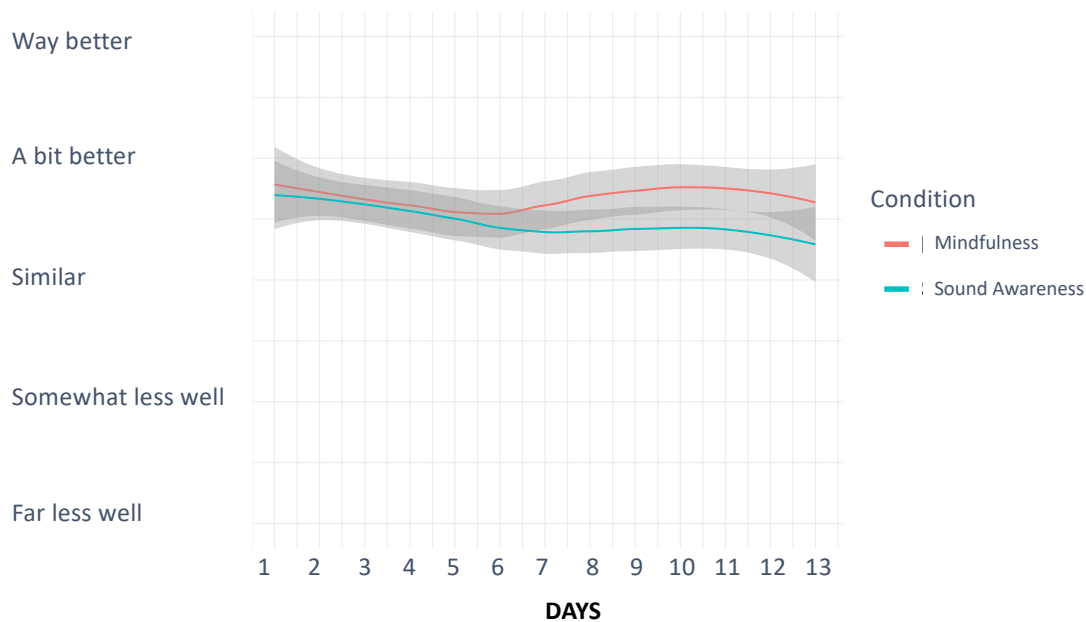


Figure 6.10. Evolution of children’s mood after the practice, for each intervention group, over the first 13 days of the long-term intervention. The grey shading represents the 95% confidence interval around the estimate.

Children’s perception of their sound environment

The sound awareness intervention was specifically designed to help children and teachers regulate their sound environment, in comparison to the mindfulness intervention, which was more general and did not specifically target children’s attention to sound and noise. As such, the sound awareness booklets contained more information about how children perceived their environment.

Pleasant and unpleasant sounds

For each day of practice, children were asked what were the most pleasant and unpleasant sounds they heard in their environment. The first thirteen days of practice provided data for children from both classes. However, over time, there was a growing

proportion of children leaving the answer field blank (from 0% at Day 1, to 26% at Day 13), or answering “nothing” or “I don’t know” (from 24% at Day 1 to 47% at Day 13). Furthermore, and in contrast to when they reported their feelings (see section: “Children’s feeling after the practice”), some children were repetitive in their answer and always reported the same sound. Data from the first day of practice will therefore be the focus of the analyses. The most frequent unpleasant sound children mentioned was that of the canteen (26%), and the most frequent pleasant sound was that happening during the “silence game” (21%). This might seem paradoxical, since children were supposed to be quieter during the “silence game”, but it might be an indication that they enjoyed the activity. Complete wordclouds are provided in Figure 6.11.



Figure 6.11. Wordclouds representing the most unpleasant (left panel) and pleasant (right panel) sound children reported to hear during the first day of the intervention. A bigger font corresponds to a bigger frequency, and words that were reported a similar amount of time are depicted in the same colour.

Silence game

The class Sound 1 performed the “silence game” 13 times, and the class Sound 2, 33 times. Again, only the first 13 days of practice were selected to provide a comparison between the two groups (see Figure 6.12). Children’s progression was neither at ceiling, nor linear. Instead, regular variations occurred between days where the class managed to stay silent for the full 3 minutes, and other days when the silence was broken after half a minute¹¹. The class Sound 1, however, reached quite a stable performance during the last few days of practice, being silent for the full 3 minutes. The interval between the different days of practice was not regular, within each class, and across classes. Since only one data point was available per class and day of practice, inferential tests could not be carried out. However, exploratory analyses did not indicate systematic associations between children’s performance and the length of the interval between the sessions, or the day of the week.

Estimation of noise levels

The estimation of noise levels corresponded to the weekly activity. Again, the class Sound 1 practiced less frequently than the class Sound 2. They estimated the noise levels generated by 4 and 10 activities respectively (see Figure 6.13). A great variability was observed both within and between the two classes. When children were asked to get up, the class Sound 1 was 15 dB louder than the class Sound 2 (90dB compared to 73dB). However, children from both classes tended to underestimate the noise levels.

¹¹ Even when taking into account the full 33 days of practice in the class Sound 2, ceiling performance was not reached, and fluctuations were still prevalent.

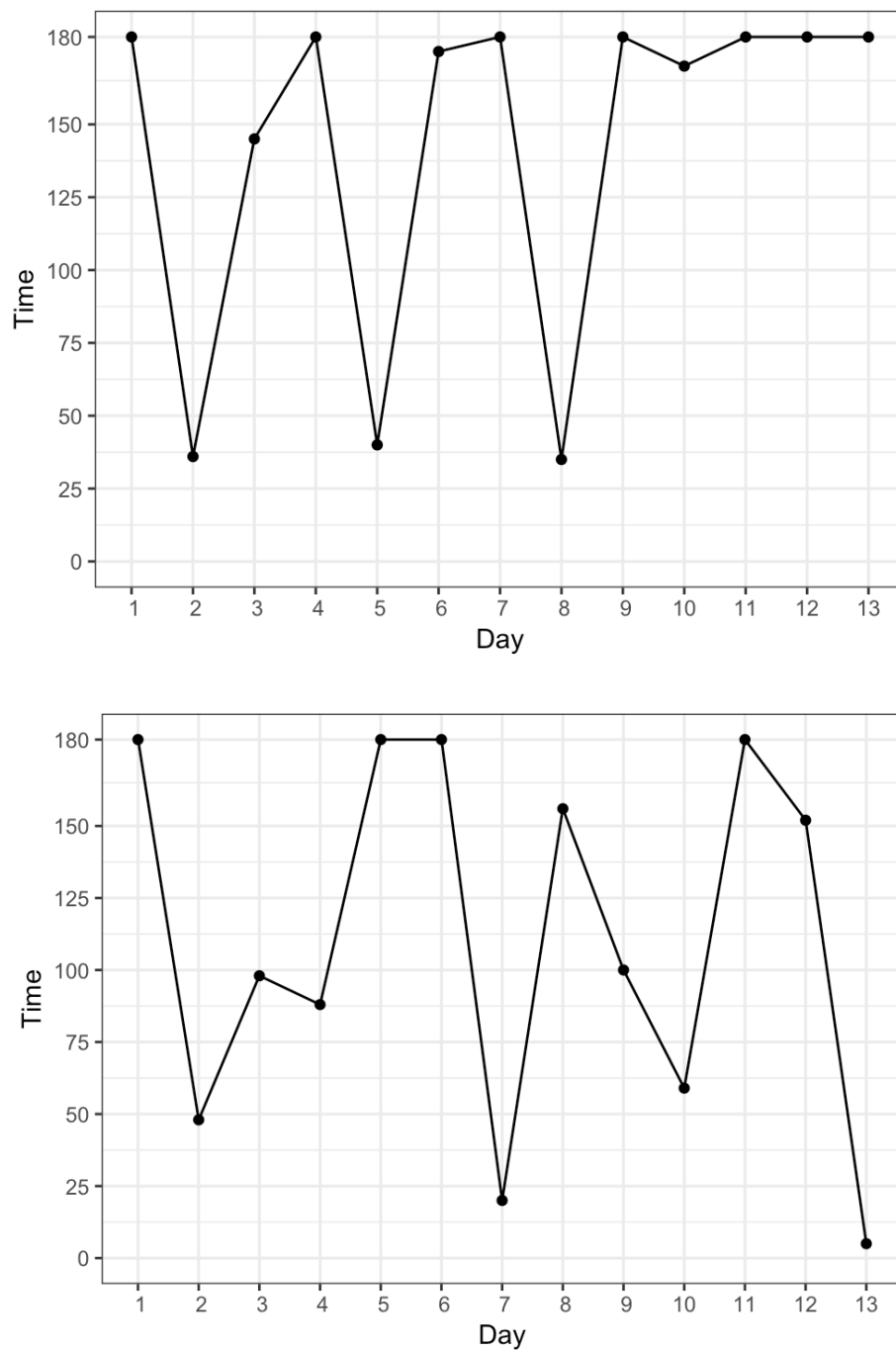


Figure 6.12. Diagrams depicting the amount of time (in seconds) children managed to stay silent, for each day they performed the “silence game”, in the class Sound 1 (top panel) and Sound 2 (bottom panel).

When asked to get up carefully, children from the two classes generated around 70dB. Most of the children from the class Sound 1 underestimated the noise levels, whereas the variability was much greater in the class Sound 2. Similarly, when asked to take a book from their drawer, most of the children from the class Sound 1 underestimated the amount of noise they were generating (80dB). Children in the class Sound 2 generated around 60dB, and their estimates were either above, under, or close to this value. Finally, when children all clicked on their BIC pens, they generated noise levels around 65dB. Most of the children in the class Sound 2 underestimated this value, while children in the class Sound 1 showed were either close, under, or above the actual value. Results from the six last activities, performed in the class Sound 2, are shown in Figure 6.13.

Note that the data generated from these activities were mainly for educational purposes (i.e., to invite children to think about the amount of noise they generate), and were not intended to provide a complete and reliable estimate of noise levels for different activities in the classroom (see Shield & Dockrell, 2004 for a broader survey). In the present activities, there was no control over who took the measures and from which location in the classroom. However, noise levels ranged from moderate (50dB) to high values (90 dB), which is what could be expected in a primary classroom (Erickson & Newman, 2017; Shield & Dockrell, 2004).

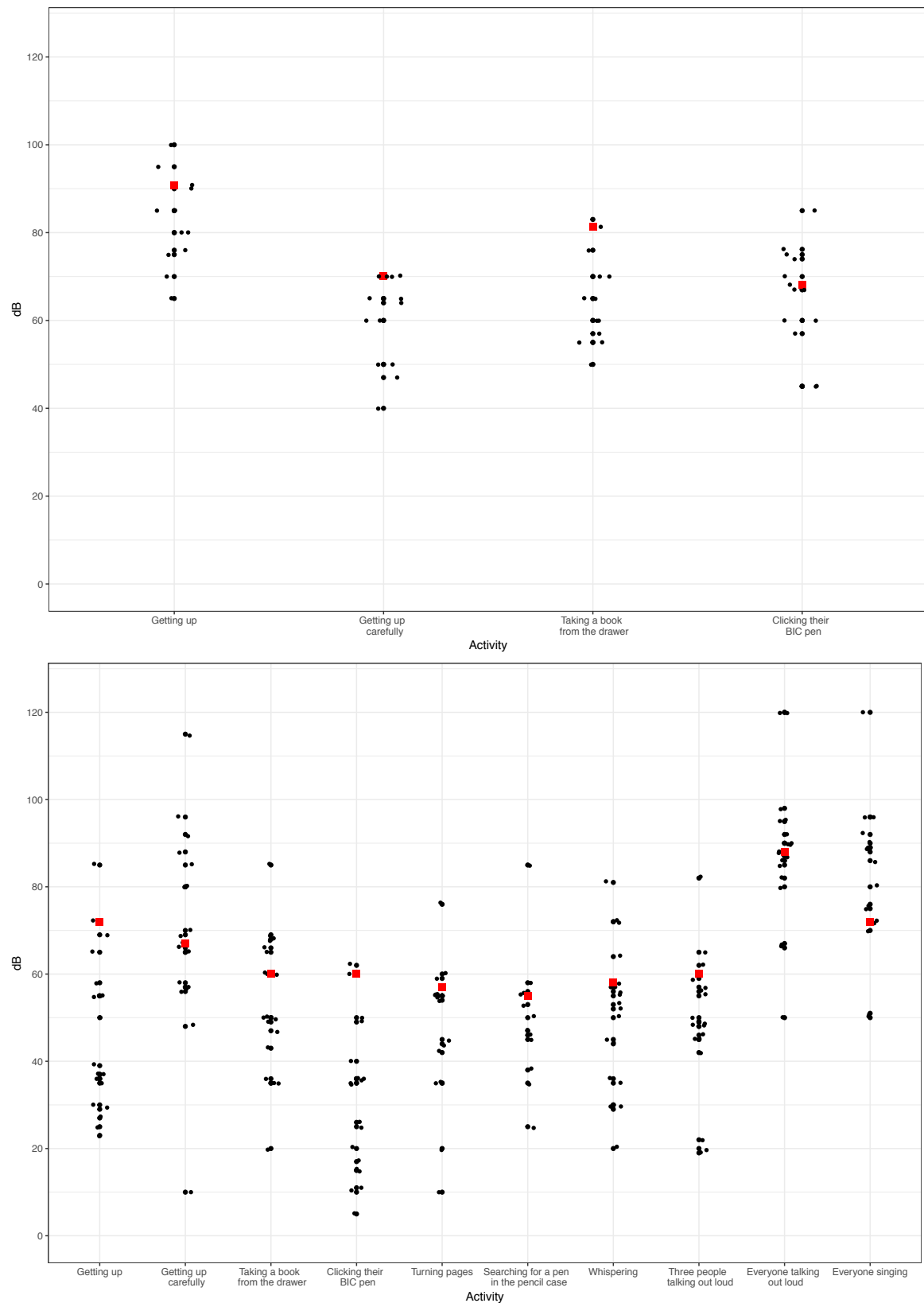


Figure 6.13. Estimation of noise levels in the class Sound 1 (top panel) and Sound 2 (bottom panel). The red dot shows the value indicated by the sound level meter.

6.2.5. Discussion

The present chapter reports the implementation of two types of interventions that took place in four primary classrooms. One intervention was aimed at raising children's awareness about noise: how it is defined and measured, how it can affect concentration and wellbeing, and how we can try to regulate it. The second intervention, mindfulness, was aimed at promoting a more general regulation of children's attention, emotions and thoughts, by encouraging present-moment awareness of their subjective experience. Four hours of workshops were delivered by external experts (which corresponded to the short-term component of the program), after which materials were directly transmitted to teachers for a daily implementation of the intervention (that was the long-term component of the program).

Fidelity measures revealed great variability in the way the classes implemented the long-term interventions. Over the 40 days that were available to practice the daily activities, some children could practice for as little as 9 days or for up to 33 days. Within each intervention group, one class practiced more than the other. However, despite these variations, there were very little differences between classes regarding children's feedback about the interventions. Most children liked the activities, found them useful and not difficult. However, when analysing the answers separately for each intervention group, it was noticed that children did not like the long-term mindfulness activities as much as the short-term ones, and that they found them less useful. This might be due to different factors. The material used during the long-term intervention focused on guided meditation exercises, whereas the short-term component also included yoga postures. Removing this dimension might have lowered children's interest. Furthermore, Kabat-Zinn (2003) points at the role of the

instructor's own relationship to mindfulness when guiding the practice. The presence of a trained expert during the short-term interventions might have fostered children's engagement by providing a role model, in comparison to solely listen to audio files during the long-term intervention. It should be noted that the present study is among the minority of studies reporting participants' acceptability of mindfulness programs - only a third of the school-based mindfulness interventions reviewed by Zenner, Herrnleben-Kurz, & Walach (2014) included such an assessment.

Individual booklets offered a window into children's reactions for each day of practice during the long-term interventions. The participants were asked how they felt after the practice, and how their mood and attention evolved compared to before the practice. Children reported more positive than neutral or negative feelings after the practice. "Calm" and "Tranquil" were the most frequently reported positive adjectives in the two intervention groups, which could hint at the idea that the classrooms would be quieter. Moreover, children reported that their mood and attention were better after their daily practice. However, mixed models revealed that it did not correspond to a gradual and linear improvement over time. In other words, the improvement in mood and attention was not strengthened as children completed more sessions. Instead, it diminished slightly over time in the two intervention groups, when considering children's attention, and in the sound awareness group, when considering their mood. Furthermore, different trajectories were noticed across children. Some of them were constant in their answers, whereas others were characterised by fluctuations between days of improvements and days during which the practice seemed to have worsen their mood and attention.

The present results are consistent with recent reviews of school-based mindfulness interventions, pointing to a positive effect on participants' capacity to regulate their emotions and attention (Felver et al., 2016; Zenner et al., 2014). However, in contrast with most of the available studies, children's feeling, mood and attention were assessed *directly* after their practice, and every time they were engaged in a mindfulness activity.

It is possible that children reported positive effects because they were prone to acquiescence bias. However, as noted above, fluctuations in children's answers over time indicated that, in the event that such bias existed, it was not systematic. Some scepticism could also be raised by the fact that children have lower metacognitive skills than adults, and might therefore not be fully aware of the impact of mindfulness on their mood and attention. If one's interest is in children's subjective wellbeing, tackling their first-hand experience does seem necessary. It should be noted, however, that third-party assessments (measures of attention from teachers or parents), could be associated with smaller effect sizes (Zenner et al., 2014). A comparison of the present results with behavioural tests of attentional skills would be relevant (Felver et al., 2016). Given the difficulty of running behavioural tests every day, Chapter 7 will return to a more traditional pre and post-test design to assess the effect of the interventions on attention, using measures (such as the Flanker task) that have previously been used in the mindfulness literature (e.g. on a child population by Biegel & Brown, 2010; on an adult population, by Tang et al., 2007), and in previous chapters.

The fact that the subjective improvement in children's attention and mood is also present in the sound awareness group suggests that it might not be specific to mindfulness practice. The novel aspect of the interventions, that is to say, the use of educational material that is not

typically included in the curriculum, could have induced a positive mood in children. By definition, no modification in teaching practices were introduced in the waiting-list control group, so data from individual booklets were therefore not available. However, it should be noted that both the sound awareness and the mindfulness interventions invited children to pay more attention to their sensory environment. In the sound awareness group, children were especially invited to pay attention to sounds and noises. In the mindfulness group, sensory awareness was not specific to the auditory modality; children were invited to stimulate their sense of vision, olfaction, taste and touch during the meditation and imagination exercises. In both cases, dedicating a moment during the day to “pause” and pay attention to one, or several senses, might have led children to feel calmer and more attentive.

Additional data from the sound awareness group gave more information about children’s perception of noise in the classroom. During the first day of their practice, over one fifth of the children from this group reported that the most pleasant sound they heard during the day was that of the “silence game”. This game aimed to better regulate noise levels by challenging children to stay quiet – noise being detected by visual panels installed on the classroom’s wall. Children therefore seemed to like the game and the atmosphere it created. This was partly confirmed by their final feedback, 50% of the children reporting that the activities changed the atmosphere in class, by rendering it quieter. However, the “silence game” did not seem to be fully mastered (children did not reach a plateau, in the sense that they would manage to stay quiet for the full three minutes after few days of practice). Furthermore, children seemed to have difficulties estimating the amount of noise generated by different classroom activities. In particular, several children in the class Sound 2 thought that classroom activities such as getting up, or actioning their BIC pen, generated less than

40dB, which is quite unrealistic – in classrooms, as children were instructed during the sound awareness workshops, noise levels are mostly within the range of 50-70dB. It is therefore unsure whether the sound awareness intervention led children to be better aware of the noise levels in the classroom, and to better regulate them. Chapter 7 will test whether the sound awareness and the mindfulness interventions were associated with a reduction in classroom noise levels. This way, and despite the uncertainties regarding the efficiency of the “silence game”, it will be possible to test whether children’s sensation of feeling calm, tranquil, and more attentive, went in hand with physical changes in their auditory environment (Bulunuz, 2014).

6.3. Conclusion and future directions

To sum up, the present chapter assessed the feasibility of implementing mindfulness and sound awareness interventions in primary classrooms, including both short-term, expert-lead, and long-term, teacher-led activities. Despite the variability in the frequency with which teachers implemented the long-term component, the activities were well-received by the children. They reported that their mood and attention improved after the activities, although this improvement did not seem to get stronger over time. Chapter 8 will compare these results with pre and post analyses focused on: behavioural assessments of executive functions (including attentional skills), children’s reactions to noise (using the questionnaire presented in Chapters 4 and 5), classroom noise levels, and, ultimately, school performance. This will strengthen the actual evidence and will provide a better comparison with the results from previous chapters.

Chapter 7 - Testing the impact of school interventions on classroom noise levels, children's executive functions, school performance and reactions to noise

7.1. Chapter overview

This chapter extends the findings reported in Chapter 6 by analysing the impact of the mindfulness and sound awareness interventions on children's cognition and well-being. Chapter 6 tracked children's self-reported feelings and changes in mood and attention as they were engaged in the interventions. Chapter 7 adopts a more traditional pre- and post-test design, using behavioural tests of executive functions (inhibitory control, sustained attention, working memory and response inhibition), self-reports of mind-wandering, switching skills, and reactions to noise. These measures have been shown to be associated with each other in Chapters 4 and 5. Tests of reading comprehension are also included as a measure of children's school performance. Finally, changes in classroom noise levels, as recorded by sound level meters, are investigated. The majority of measures are common to those used in previous chapters, to allow for a comparison of results across chapters.

The methodological approach used in this Chapter is shown in Figure 7.1. Most of the measures were collected in a classroom context, with the exception of the laboratory-based assessments of attentional skills.

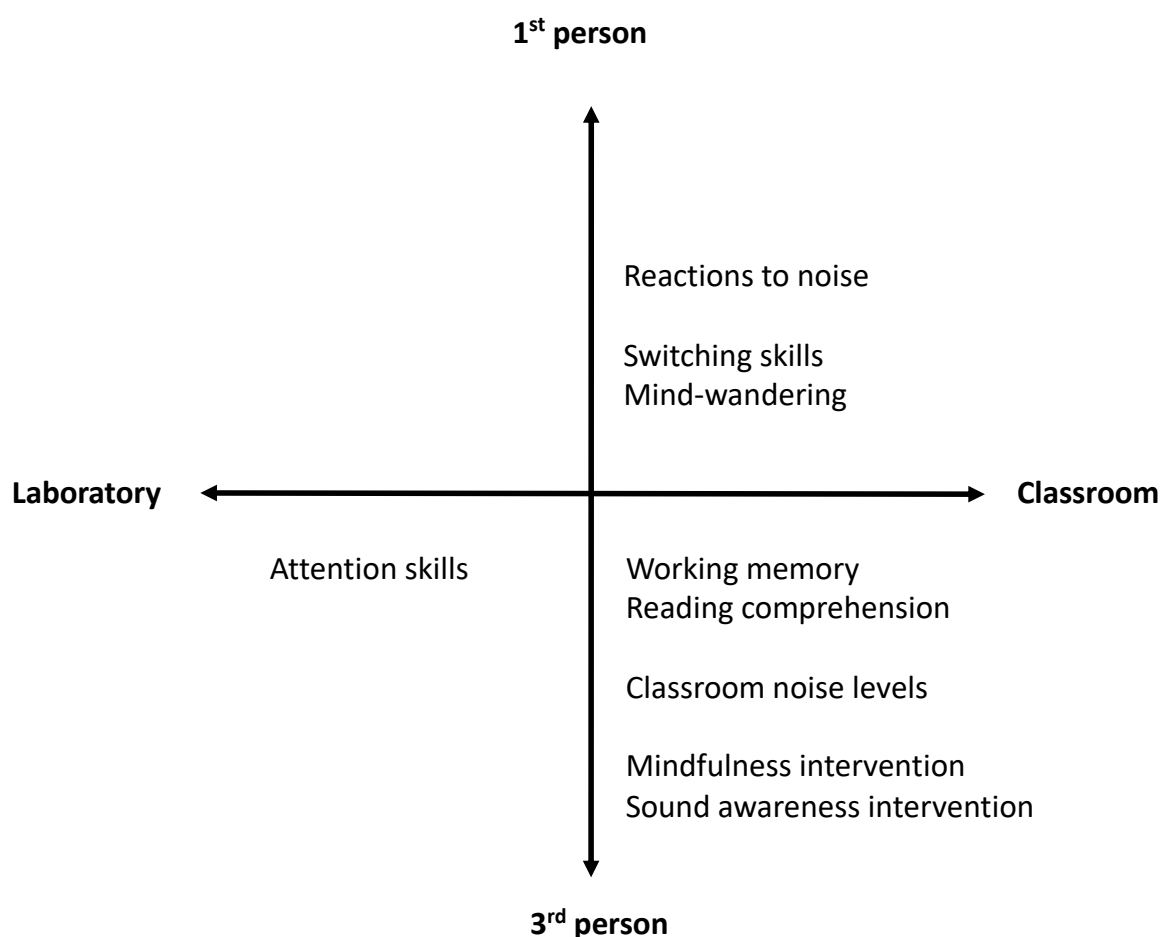


Figure 7.1. Methodological approach used in Chapter 7

7.2. Experiment 3: Testing the impact of school interventions on classroom noise levels, children's executive functions, school performance and reactions to noise

7.2.1. Introduction

Chapter 7 introduced the implementation of mindfulness and sound awareness interventions in primary classrooms. These interventions were chosen because they can impact on the way children perceive and generate noise. Although classes varied in the frequency with which they practiced the activities, the interventions were well received by the children. Children indicated positive feelings, as well as improvements in their mood and attention after the practice. One key limitation of Chapter 6 is that it focused on self-report measures – this was also the case for 96% of the mindfulness studies reviewed by Felver et al. (2016), and 67% of the studies reviewed by Zenner et al. (2014). One reason for moving to using behavioural tests is that it allows for a better understanding of the cognitive mechanisms that might be affected by the interventions. Evidence on mindfulness practice will be the main focus of the current review, as the literature is more developed, and this will be put in perspective as to what effects might be expected from sound awareness workshops.

Theoretical models (e.g. Bishop et al., 2004; Chiesa, Calati, & Serretti, 2011; Shapiro, Carlson, Astin, & Freedman, 2006) suggest that mindfulness trains multiple executive functions. In Kabat-Zinn (2003)'s words, mindfulness is “the awareness that emerges through paying attention on purpose, in the present moment, and nonjudgmentally to the unfolding of experience moment by moment” (p. 145). Such practice implies the need to sustain one's

attention (i.e. to maintain a state of vigilance over a prolonged period of time), and to inhibit unwanted thoughts, emotions and sensations, as well as external distractors in order to refocus attention to the present moment. Switching skills can also be involved, in order to consider thoughts and emotions from different perspectives (Diamond, 2013), take distance from habitual and automatic responses, and ultimately get back to a focused state of attention. All these skills are implicated in the development of metacognition (that is to say, the monitoring and control over one's thoughts and emotions) and of self-regulation (Bishop et al., 2004; Shapiro et al., 2006).

Whereas the theoretical models of mindfulness highlight modifications in the attention we pay to *internal* stimuli, most of the available empirical evidence focuses on attention to *external* stimuli, using, in particular, the Attention Network Test (ANT; Fan, McCandliss, Sommer, Raz, & Posner, 2002; Rueda et al., 2004). The ANT posits the existence of three uncorrelated networks of attention: 1) Alerting (an overall state of alertness, not oriented in space), 2) Orienting (the direction of attention to a specific stimulus or point in space), and 3) Executive control (the resolution of conflicts between competing stimuli, and the resistance to irrelevant distractors). Within this framework, sustained attention can be understood as requiring alerting and orienting processes, whereas switching skills and inhibition relate to the executive control component.

When looking at the child literature, mindfulness training with novices seems most likely to impact the executive control component of attention, in comparison to the other networks. Using the ANT, Biegel and Brown (2010) reported an improvement in executive control among a sample of 7- to 9-year-olds who followed three sessions of 15 minutes of mindfulness for

five weeks. Napoli, Krech, and Holley (2005) compared a group of 6- to 9-year-olds who did twelve fortnightly sessions of mindfulness, each lasting 45 minutes, with a business-as-usual control group. The mindfulness group improved in its capacity to identify targets among distractors, but there was no change in sustained attention. Caution is warranted, however, since Biegel and Brown (2010) did not include a control group, and since Napoli et al. (2005) did not provide measures of baseline performance for each group. Furthermore, a certain amount of practice might be necessary for changes to occur, since single mindfulness sessions lasting 3 minutes (Leyland, Emerson & Rowse, 2018), or 15 minutes (Lim & Qu, 2016) were not associated with changes in preschoolers' performance at executive function tasks (Leyland, Emerson & Rowse, 2018) or at the ANT (Lim & Qu, 2016).

Despite these limitations, the evidence from children matches that from adults. Again, executive control is especially likely to be improved after short (but repeated) mindfulness training, whereas improvements in sustained attention require extended practice (see the reviews of Chiesa et al., 2011 and Tang et al., 2015). Using the ANT with a sample of undergraduate students, Tang et al. (2007) reported improvements in executive control, but not in alerting and orienting, after five days of mindfulness training for 20 minutes a day. This improvement was not shown in a control group involved in relaxation practice. Wenk-Sormaz (2005) used a different executive control task, the Stroop Task, which requires the participant to inhibit a dominant response (reading a colour word) in order to focus on the font colour. Participants were tested before and after their third 20-minutes mindfulness session. Whereas there was no significant difference in Stroop interference at baseline between the mindfulness group and two control groups (one engaged in a memory task, one resting), the mindfulness group showed a lower interference at post-test.

The cognitive effects of short-term mindfulness training do not appear to be limited to executive control. Adults also showed improvements in working memory after following eight classes of 45 minutes (spread over two weeks, Mrazek, Franklin, Phillips, Baird, & Schooler, 2013), or four weekly sessions of 20 minutes (Zeidan, Johnson, Diamond, David, & Goolkasian, 2010). In Mrazek, Franklin, et al. (2013)'s study, improvements in performance were mediated by a diminution in mind-wandering.

An impact of mindfulness training on executive control and working memory is of special interest when considering the impact of noise on children's task performance. Chapter 3 showed that five to eleven year children with high executive control were better protected against the effects of moderate classroom noise when prompted to generate original answers at a creative task (Massonnié et al., 2019). Furthermore, in Chapter 2, children with high working memory skills were less impaired by noise when performing a mathematics task. Therefore, nurturing executive control and working memory might potentially help children to cope with noise, when engaged in specific learning tasks. However, caution is warranted. Training programs focused on executive control and working memory have the potential to improve these two skills, but the evidence for far transfer is limited (Diamond & Ling, 2016). In other words, the benefits might not directly generalise to untrained academic skills.

Another potential mechanism through which mindfulness can impact on school performance is via its effects on children's behaviour. After 15 mindfulness sessions of 15 minutes (spread over 5 weeks), teachers reported an improvement in low-income primary school children's capacity to pay attention in class, to control their behaviour, to participate in class activities, and to respect each other (Black & Fernando, 2014). Furthermore, two case studies with

children with high levels of disruptive behaviour (Felver, Frank, & McEachern, 2014), and ADHD (Carboni, Roach, & Fredrick, 2013) showed improvements in academic engagement, measured by classroom observations. Felver et al. (2014) implemented 5 sessions of 20-30 minutes, whereas Carboni et al. (2013) adapted the dose to the needs of each student (between 3 and 17 sessions being necessary to observe improvements). Finally, the self-reported tendency to be mindful in everyday life (e.g. not performing tasks in autopilot, being aware of one's emotions) has been correlated with the capacity to inhibit habitual and dominant motor responses (response inhibition) on a sample of 9- to 11-year-olds (Oberle, Schonert-Reichl, Lawlor, & Thomson, 2012). Better academic engagement, associated with less disruptive behaviour, can promote optimal learning conditions and have positive effects on school performance in the long run. Since noisy behaviours such as moving around, or talking to other people when they are engaged in academic work are considered disruptive behaviours, a reduction in classroom noise levels might also be expected as a bi-product of mindfulness interventions. It is possible that sound awareness workshops could also have a positive impact on disruptive behaviours, by training children to be aware of and to regulate the noise they generate. However, these changes might happen progressively over time, and might only be noticeable after a long-term intervention (Bulunuz, 2014).

A final dimension that is worth highlighting about mindfulness training (after its potential effects on executive functions and behavioural control) is how it can impact on people's perception of their environment. The adoption of an open and non-judgemental attitude is central to mindfulness (Kabat-Zinn, 2003; Rempel, 2012), and goes in hands with the training of attention. This could seem paradoxical: Trainees would be more aware of their environment, while avoiding immediate judgements. The implications for the perception of

noise in the classroom are unclear. Would children pay more attention to noise? And would they be, at the same time, less annoyed, because they adopt a non-judgemental attitude? A question arises about whether mindfulness training could avoid the pitfalls of sound awareness interventions, that could render children more aware and, simultaneously, more annoyed by noise (Bulunuz, 2014).

7.2.2. Aims of the current investigation

The current study compares three groups of children, using measures of: 1) their reactions to noise, 2) executive functions, 3) school performance, and 4) classroom noise levels. One group received a mindfulness intervention, one group a sound awareness intervention, and one group acted as a waiting-list control. It is important to assess the overall impact of the interventions by comparing the mindfulness and sound awareness groups to the waiting-list control. However, interventions create a novelty effect by the fact that they differ from the “business-as-usual” curriculum. It is therefore also necessary to compare the two intervention groups with each other. The sound awareness intervention could have a positive impact on disruptive behaviours, by training children to be aware of and to regulate the noise they generate, without impacting the same cognitive mechanisms (executive control, working memory) than mindfulness training. The hypotheses are detailed below.

Hypotheses

Generation of noise

It was predicted that both the mindfulness and sound awareness interventions would reduce noise levels in the classroom, especially after the long-term intervention, since it gives

children and teachers the opportunity to fully integrate and incorporate the new activities in their daily school life. Whether this effect would go in hand with improvements in behavioural control had to be tested.

Perception of noise

In line with the current literature, it was predicted that mindfulness would improve children's executive control, working memory, and would reduce mind-wandering, while favouring the adoption of a non-judgmental attitude towards noise. This would therefore reduce feelings of distractibility and annoyance from noise. It was unclear whether these effects would be noticed in the sound awareness workshop. Indeed, unless children get a better control over the emotions induced by noise, a greater awareness of noise could induce more annoyance (even if noise levels are actually lower). Therefore, the mindfulness intervention was expected to have stronger effects in reducing negative reactions to noise.

School outcomes

To the extent that the interventions reduce noise levels, they are likely to induce a more positive learning context for children, favouring access to academic content (i.e. hearing the teacher), and reducing interference from noise when engaged in school tasks. Improvements in school performance were therefore expected. However, given the potential of mindfulness practice to impact executive control and working memory (which have been associated with better school performance), its effects were expected to be stronger.

7.2.3. Methods

7.2.3.1. Participants

Data were collected from the same participants as in Chapter 6. The sample included 109 children, from 8.70 to 11.38 years of age ($M = 10.03$; $SD = .60$). The children came from six different classrooms and were in Year 5 or Year 6. Two classes were assigned to each of the following conditions: 1) mindfulness intervention ($n = 41$), 2) sound awareness intervention ($n = 34$), 3) waiting-list control ($n = 34$). Details about the classes' assignment to different conditions are in Table 6.1 (Chapter 6).

7.2.3.2. Procedure

A timeline of the project can be found in Figure 6.5 (Chapter 6). Each testing period was spread over a maximum of two weeks and a half, and followed the same procedure. Individual testing sessions were carried out outside of the classroom and lasted around 15 minutes. Under the supervision of the experimenter, participants performed the Letter Cancellation Task, the Flanker task, and the Sustained Attention to Response Task (SART), in this same fixed order. Collective sessions took place in class, under the supervision of the teacher. A booklet was distributed to each child, containing guidance for the Working Memory and Reading Comprehension tasks. A mathematics task was included after the reading comprehension task, but data were missing for two classes at Post-test 1, so it will not be discussed further here. The survey assessing children's reactions to noise was distributed on the same day than the collective session, or a day apart.

7.2.3.3. Measures

Socio-demographics

On the consent form, the child's primary caregiver was asked to specify their number of years in higher education. This was to assess potential differences in socio-demographic backgrounds between the three intervention groups.

Switching skills and **mind-wandering** were measured in the same way as in Chapter 4 and 5, using self-report questionnaires derived from Carriere, Seli, and Smilek (2013) and Mrazek, Phillips, Franklin, Broadway, and Schooler (2013).

Inhibitory control was assessed with the child Flanker task (Anwyl-Irvine et al., 2019) that has been adapted from the ANT (Fan et al., 2002; Rueda et al., 2004) and used throughout this thesis. Mindfulness studies on children (Biegel & Brown, 2010) and adults (Polak, 2009; Tang, Hölzel & Posner, 2007) have used similar tasks. Accuracy (the proportion of correct trials) and reaction times for correct answers (RTs) for congruent and incongruent trials were recorded. RTs under 200ms (being too short to follow the perception of the stimuli), and above 3 standard deviations from the mean of each participant were excluded (Koivisto & Grassini, 2016; Rutiku et al., 2016; Whelan, 2008).

Sustained attention was measured with the Letter Cancellation task and the Sustained Attention to Response Task (SART) introduced in Chapter 5.

In the Letter Cancellation Task, participants had to find and cross out all the "T" and "G" on a A4 paper sheet. The total score took into account speed and accuracy, according to the following formula: (number of correct responses/total number of targets) x (number of

correct responses/total time), see Geldmacher (1996). Higher scores indicate better performance.

In the SART, participants had to press the space bar when they were presented with a picture of a mole (Go trials, 76% of the trials), and to withhold their response when seeing an eggplant (NoGo trials, 24% of the trials). Reaction times for correct answers at the Go trials were recorded. Reaction time variability was calculated for each child as the standard deviation of their reaction time distribution (McVay & Kane, 2012).

Response inhibition, reflecting children's capacity to withhold a dominant response, was derived from the SART (also see Shapiro, Wong, & Simon, 2013) and was calculated by subtracting the Accuracy to NoGo trials from the Accuracy to Go trials.

Verbal working memory was measured with the collective backward digit span task used in Chapter 5. Children heard a series of digits through speakers, and had to report them backward on their individual booklet. Children were presented with four trials of a given list length – evolving from two, to eight digits. Stopping rules were applied *a posteriori* - scoring stopped when children missed more than one trial for a given level. The total number of correct answers given before this stopping rule was recorded.

Reading comprehension was assessed by two different narrative texts (Bianco et al., 2014), used at each time point. The first text (338 words) was followed by eight questions (one multiple-choice question, seven open questions). Two assessed the understanding of literal information (i.e. information directly stated in the text), three required the participant to draw inferences at the passage level, three tapped into global inferences at the level of the

entire text. The second text (410 words) was followed by ten questions (four multiple choice and six open questions; two assessing literal understanding, four local inferences, four global inferences). Each answer was coded 0 (incorrect) or 1 (correct) according to a pre-established grid. The two texts were normed on more than 400 French Year 5 pupils, and one of the texts was also normed on 382 Year 6 pupils, indicating that performance was normally distributed, and not at ceiling. The same texts were used at the three time points, to make sure the same abilities were assessed – repetition effects were controlled for by the waiting-list control group. Internal consistency was calculated on the pre-test data, across the entire sample, and was satisfactory ($\alpha = .70$).

Children's reactions to noise were measured with the school survey presented in Chapter 4 (see Appendix D). Attention capture, Interference and Annoyance from noise were measured based on the questions extracted from the factorial analyses in Chapter 4 (see section 4.2.4.2 and Table 4.2). Attention Capture was measured using three items, Interference four items, and Annoyance five items.

Noise levels

At the beginning of the study, sound level meters were installed on the front wall of the classrooms, near the white board. Two different designs were ordered from an external company (Levelscore; N° Siret 831 005 343 00015). For the control and mindfulness groups, the sound level meters took the form of black, squared, wooden boxes painted in black. These were around 15 cm³ in size. For the sound awareness group, the sound level meters were wider, rectangular visual displays, that had the option to light up according to the ambient noise level. This function was used during the long-term interventions, and the visual display

was turned off for baseline measurements of noise levels at pre-test. The two types of sound level meters were equipped with an Analog Sound Sensor (V2.2) that was programmed to record sound pressure levels in decibels over one-minute samples. Short samples (of two minutes) were also used by Shield and Dockrell (2004) and judged as good indicators of fluctuations in noise during the day. The data were sent over the Internet to an online (anonymised) database programmed in Structured Query Language (SQL). In the event of an interruption of the Internet, the data were stored on the sound level meters for few hours, before being synchronised. Sound level meters were calibrated before installation and, during the study, occasional checks against a portable sound level meter (TENMA 72-6635, with an accuracy of ± 1.5 dB) were carried out.

7.2.4. Results

In the results section, T1 refers to the pre-test data, T2 to the data following the short-term intervention, and T3 to the data following the long-term intervention.

7.2.4.1. Pre-processing

Inhibitory control (Flanker task). For each group, time point, and trial type, the mean accuracy was above 97%. None of the children performed at chance (i.e. accuracy < 60%). Reaction times for correct answers were therefore retained as the main measure of selective attention.

Sustained Attention to Response Task. For each group and time point, the mean accuracy at Go trials was above 97%. None of the children performed at chance (i.e. accuracy < 60%). Reaction time variability was calculated on a minimum of 75 trials per child, making it a suitable measure.

Response inhibition (derived from the SART). The high accuracy at Go trials (reported above) indicates that children successfully learned the dominant response (pressing the space bar when they saw a mole). It makes it possible to use the difference score (Accuracy at Go trials – Accuracy at NoGo trials) to measure response inhibition.

Verbal Working Memory. As explained in Chapter 5, several children did not follow the rules for the collective working memory task. They wrote down the numbers as they heard them (instead of waiting for the list to be finished) from right to left (to mimic the reversing process). Therefore, only scores below 27 were included in the analyses, in order to avoid these ceiling level cases unduly influencing the results. This procedure is open to debate, but it is the most conservative approach, since it focuses on children who engaged in the task as instructed and did manipulate the digits in memory.

Noise levels. To put classroom noise in perspective with the individual data collected on children, only samples that were collected during the Pre-test, Post-test 1 and Post-test 2 were included. These testing periods corresponded to 9, 7 and 10 days in class¹² (for the Pre-test, Post-test 1 and Post-test 2 respectively). Furthermore, teachers' weekly schedule was

¹² As specified in the Procedure section, testing periods were spread over two weeks and a half maximum, but these include week-ends and Wednesdays, when children were not in class.

collected, and only samples that were taken during lessons were kept in the analyses. In other words, noise levels recorded during playground time, when children were outside, were excluded. The total number of available samples varied between classes, due to the aforementioned filtering processes, and to technical issues. The class Control 2 did not have a working Internet connection despite regular contacts with service providers from September, 2017. This resulted in a considerable loss of data, which could not be stored off-line over prolonged periods of time. Very few samples could be obtained from this class during testing periods, so, due to the risk of this data not being representative, it was decided not to include it in the analyses. Note that this class was the one that contained the smallest number of participants ($n = 9$). For the remaining classes, two-hundred samples of one-minute were randomly selected and used to derive estimates of average noise levels. The samples corresponded to different days and hours. They can therefore be considered as largely independent.

7.2.4.2. Descriptive statistics

Descriptive statistics are reported in Tables 7.1 and 7.2. For the purpose of clarity, averages¹³ were calculated for the questionnaire measures (Switching, Mind-wandering, Reactions to noise), although latent variables will be used for inferential statistics.

¹³ Averages were calculated for children who had no more than one item missing for a given measure.

Table 7.1. Descriptive statistics for each time point and intervention group

	Control			Mindfulness			Sound		
	<i>M</i>	<i>SD</i>	<i>n</i>	<i>M</i>	<i>SD</i>	<i>n</i>	<i>M</i>	<i>SD</i>	<i>n</i>
Socio-demographics									
Age	9.70	.54	34	10.03	.55	41	10.35	.56	34
SES (Education)	2.96	1.61	23	2.87	2.57	30	3	2.89	23
Gender (% Male)	55.9		34	41.5		41	61.8		34
Executive Functions									
Flanker task T1	38.58	76.10	34	51.51	99.98	40	45.31	57.94	33
Flanker task T2	24.01	48.37	34	32.62	36.68	41	22.18	31.84	30
Flanker task T3	35.81	41.01	34	25.18	28.53	40	22.24	37.82	33
LCT T1	.1439	.0374	34	.1514	.0455	40	.1316	.0420	33
LCT T2	.1454	.0437	34	.1592	.0450	41	.1540	.0532	29
LCT T3	.1542	.0534	34	.1480	.0391	40	.1482	.0468	32
SART T1	100.24	15.82	34	99.77	18.83	40	102.52	23.49	33
SART T2	103.57	17.29	34	100.53	20.23	41	106.39	24.38	30
SART T3	100.56	20.88	34	102.47	21.20	39	105.80	20.42	33
Response inhibition T1	9.83	7.65	34	7.64	7.66	40	11.39	9.75	33
Response inhibition T2	11.36	10.35	34	7.49	7.43	41	11.57	10.61	30
Response inhibition T3	9.39	9.64	34	9.99	12.82	39	9.65	10.56	33
Working Memory T1	9.69	5.52	16	11.79	7.76	24	12.26	3.97	27
Working Memory T2	13.19	9.28	16	10.25	4.66	24	13.26	4.22	27
Working Memory T3	10.56	5.01	16	10.42	5.88	24	14.07	5.05	27

LCT: Letter Cancellation Task; SART: Sustained Attention to Response Task

Table 7.1. (continued)

	Control			Mindfulness			Sound		
	<i>M</i>	<i>SD</i>	<i>n</i>	<i>M</i>	<i>SD</i>	<i>n</i>	<i>M</i>	<i>SD</i>	<i>n</i>
School Performance									
RC T1	11.63	2.66	32	11.65	3.79	37	11.09	3.45	33
RC T2	12.24	2.91	33	12.51	3.63	39	11.27	3.55	30
RC T3	13.15	2.50	34	13.06	3.81	35	12.22	3.09	27
Questionnaire data									
Switching T1	2.81	.60	33	2.93	.56	34	3.12	.71	30
Switching T2	2.76	.65	31	2.90	.82	39	3.31	.53	28
Switching T3	2.79	.77	34	2.80	.82	34	3.07	.72	31
Mind-wandering T1	1.73	.45	33	1.96	.61	34	1.87	.71	32
Mind-wandering T2	1.70	.52	33	1.83	.60	40	1.75	.54	28
Mind-wandering T3	1.90	.61	33	2.06	.71	34	1.88	.63	31
Attention Capture T1	2.43	.90	33	2.12	.74	35	2.17	.90	32
Attention Capture T2	2.41	.94	33	2.19	.88	40	1.90	.78	28
Attention Capture T3	2.21	.86	34	2.39	.98	34	2.02	.82	32
Interference T1	2.10	.77	31	2.02	.83	36	2.18	.86	31
Interference T2	2.19	.72	33	1.96	.76	40	1.86	.80	27
Interference T3	2.19	.75	34	2.35	.79	34	1.88	.68	32
Annoyance T1	2.43	.79	33	2.18	.77	36	2.03	.76	32
Annoyance T2	2.39	.86	33	2.20	.78	40	1.90	.66	27
Annoyance T3	2.19	.76	34	2.28	.84	34	1.76	.70	32

RC: Reading Comprehension

Table 7.2. Noise levels in the six participating classrooms

	Control 1	Mindfulness 1	Mindfulness 2	Sound 1	Sound 2
T1	48.04 (6.85) [31.40-65.95]	53.14 (6.78) [38.01-68.95]	50.11 (7.41) [34.15-73.53]	54.52 (9.25) [35.45-71.92]	45.93 (8.27) [33.08-72.52]
T2	46.42 (8.20) [30.25-66.64]	52.58 (8.18) [39.39-70.32]	46.93 (7.30) [35.87-68.58]	53.01 (9.52) [34.54-77.46]	43.44 (8.96) [32.37-74.05]
T3	41.49 (8.43) [32.94-73.63]	52.00 (9.43) [40.80-76.49]	48.28 (7.49) [37.67-86.61]	44.97 (9.48) [33.41-67.63]	42.65 (9.18) [32.55-70.29]

Average values of $L_{Aeq, 1min}$ over 200 randomly selected samples in each classroom. Standard deviations are in brackets, ranges in square brackets.

7.2.4.3. Baseline differences

Potential baseline differences between the groups were tested using a one-way ANOVA, for continuous variables, and Chi-Square tests, for categorical variables. The assumption of homogeneity of variance between groups was tested by the Levene's test and verified, unless otherwise specified.

Socio-demographics

The groups differed in terms of age ($F(2, 106) = 11.69, p < .001$). Post-doc comparisons with Bonferroni correction indicated that children in the control group were younger than children in the mindfulness ($p = .034$) and sound awareness ($p < .001$) groups. Children in the mindfulness group were also younger than those in the sound awareness group ($p = .045$).

There was no significant difference between the three groups in terms of gender distribution ($\chi^2(4) = 3.33, p = .190$). Data on parental education were available for 70% of the sample (between one-fourth and one-third of the data was missing for each intervention group). Although the available data might not be entirely representative, it did not reveal a significant difference between groups ($F(2, 76) = .21, p = .979$).

Executive functions

There was no baseline difference between the three groups, for any of the executive function measures (Flanker Task: $F(2, 104) = .23, p = .793$; Letter Cancellation Task: $F(2, 104) = 2.02, p = .137$; SART: $F(2, 104) = .20, p = .821$; Response Inhibition: $F(2, 104) = 1.87, p = .160$; Verbal Working Memory: $F(2, 64) = 1, p = .375$).

School performance

Similarly, the groups did not differ at baseline in terms of reading comprehension ($F(2, 99) = .30, p = .744$).

Children's reactions to noise

Children's reactions to noise were comparable in each intervention group (Attention Capture: $F(2, 97) = 1.25, p = .290$; Interference: $F(2, 95) = .30, p = .739$; Annoyance: $F(2, 98) = 2.19, p = .117$). There were also no baseline differences in Switching skills ($F(2, 96) = 1.99, p = .143$) and Mind-wandering ($F(2, 98) = 1.21, p = .302$).

To sum up, the only variable on which the three intervention groups differed prior to the intervention was Age. It was therefore entered as a covariate in the following analyses.

Noise levels

The assumption of homogeneity of variance between groups was violated, the Levene's test being significant ($F(2, 997) = 34.89, p < .001$). A Welch test was therefore used to compare the average noise levels in the three different groups, and indicated significant differences ($F(2, 997) = 12.54, p < .000$). Games-Howell post-hoc comparisons indicated that baseline noise levels in the control group ($M = 48.04, SD = 6.85$) were lower than in the mindfulness group ($M = 51.62; SD = 7.25; p < .001$), and in the sound awareness group ($M = 50.23; SD = 9.76; p = .004$). The difference between the mindfulness group and the sound awareness group was close to significance ($p = .057$).

7.2.4.4. Intervention effects

Individual data (executive functions, school performance and reactions to noise)

To be consistent with the analyses that were carried out on the same sample in Chapters 4 and 5, regression analyses were run on MPlus 6.12, using the robust maximum likelihood estimator. Questionnaire variables (Switching, Mind-wandering, Attention Capture, Interference, Annoyance) were modeled as latent variables. For each outcome measure, two sets of models were run. In the first one, the T2 value was defined as the dependent variable and was regressed on the T1 value, Age, and Intervention Group (dummy coded). In the second set of models, T3 was defined as the dependent variable and was regressed on the T1 value, Age, and Intervention Group (dummy coded). There were 5.74% of missing data across all time points and outcome variables. Little's (1988) MCAR test was not significant ($\chi^2(4002) = 3978.55, p = .601$), indicating that data were missing completely at random.

Results from the regression analyses are presented in Table 7.3. There were significant differences between the intervention groups on Reading Comprehension, Attention Capture and Annoyance from noise (shown in bold font).

Table 7.3. Results from regression analyses testing the effect of Intervention Group, after controlling for Age and Baseline performance

	T2			T3		
	Mindful. vs Control β (p)	Sound vs Control β (p)	Sound vs Mindful. β (p)	Mindful.vs Control β (p)	Sound vs Control β (p)	Sound vs Mindful. β (p)
Executive functions						
Flanker Task	.11 (.380)	-.01 (.913)	-.11 (.240)	-.15 (.170)	-.16 (.174)	-.02 (.841)
LCT	.08 (.313)	.15 (.099)	.07 (.422)	-.11 (.163)	.04 (.626)	.15 (.055)
SART	-.06 (.576)	.05 (.687)	.11 (.273)	.06 (.594)	.13 (.280)	.07 (.449)
Response Inh.	-.18 (.060)	-.10 (.426)	.08 (.377)	.09 (.382)	-.02 (.824)	-.11 (.254)
VWM	-.29 (.115)	-.11 (.616)	.19 (.116)	-.06 (.654)	.20 (.227)	.27 (.080)
School Performance						
RC	.07 (.282)	-.06 (.378)	-.13 (.031)	.05 (.507)	-.11 (.179)	-.16 (.038)
Questionnaire data						
Switching	.03 (.817)	.18 (.105)	.15 (.118)	.04 (.727)	.14 (.285)	.10 (.419)
Mind-wandering	.10 (.381)	.12 (.418)	.02 (.872)	.08 (.566)	-.05 (.739)	-.13 (.380)
Att. Capture	.03 (.743)	-.02 (.844)	-.05 (.548)	.14 (.180)	-.05 (.619)	-.19 (.084)
Interference	-.08 (.460)	-.17 (.126)	-.09 (.411)	.12 (.286)	-.23 (.027)	-.35 (.001)
Annoyance	-.05 (.650)	-.16 (.158)	-.12 (.146)	.16 (.142)	-.10 (.409)	-.25 (.024)

LCT: Letter Cancellation Task; VWM: Verbal Working Memory; RC: Reading Comprehension.

There was a significant difference between the mindfulness and sound awareness groups when considering the evolution of reading comprehension scores from T1 to T2, and from T1 to T3. This is represented in Figure 7.2. Children in both groups performed better over time, but the improvement was more important for the mindfulness group. The improvement between T1 and T2 was of .18 points for the sound awareness group and of .86 points for the mindfulness group. Improvements between T1 and T3 were of 1.13 and 1.41 points respectively. Note that descriptive statistics also indicate an improvement over time for the control group, although this group did not significantly differ from the other two.

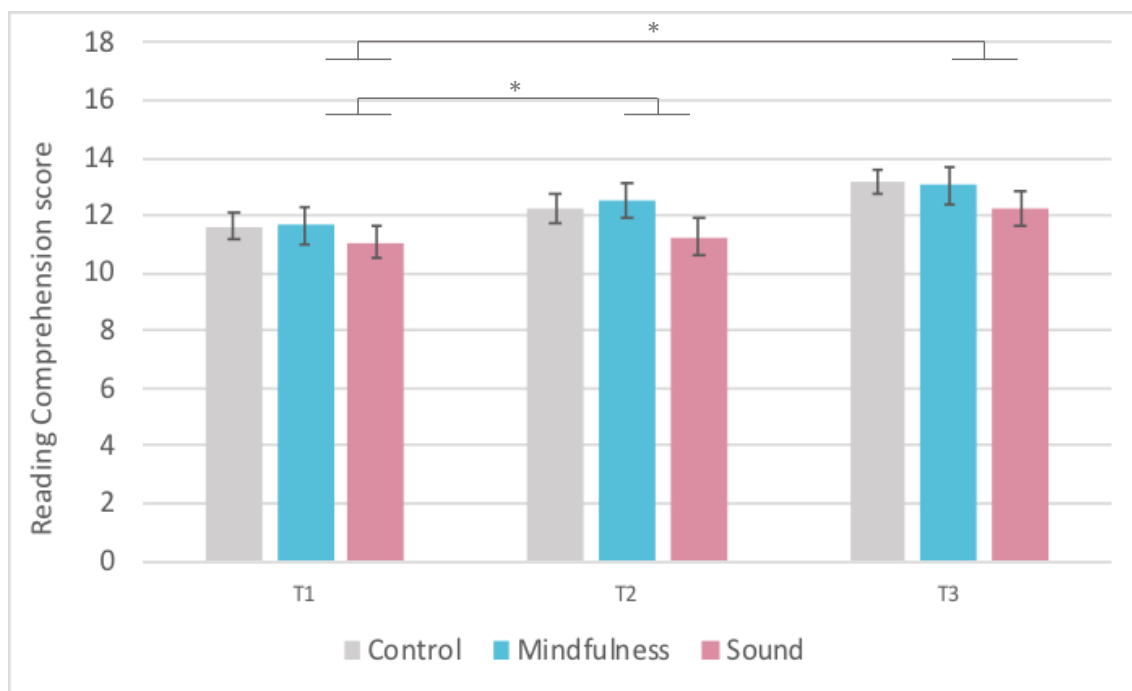


Figure 7.2. Pupils' reading comprehension scores at baseline (T1), after the short-term intervention (T2), and after the long-term intervention (T3), for each intervention group.

Error bars represent standard errors.

Children from the sound awareness group differed from both the control and mindfulness groups between T1 and T3 on noise Interference. Children in the sound awareness group reported less feelings of Interference from noise after the long-term intervention (a reduction in .30 points). Ratings stayed pretty stable in the control group (plus .09 points) and increased in the mindfulness groups (plus .33 points) - see Figure 7.3.

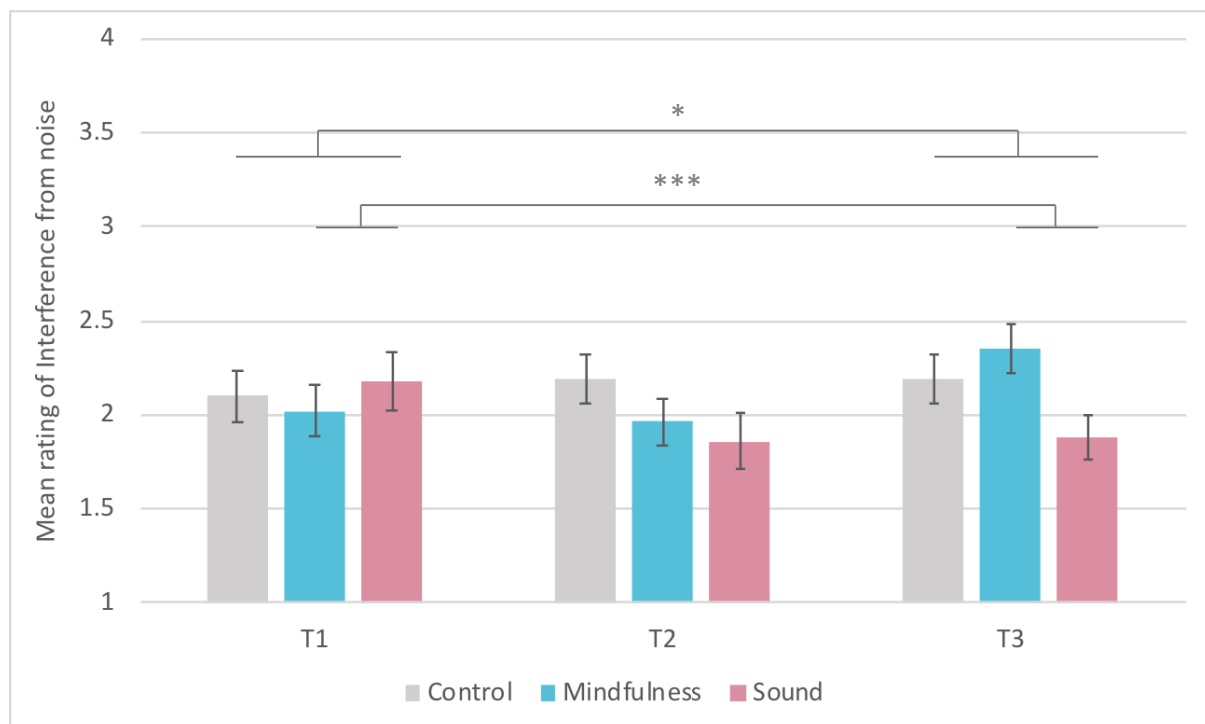


Figure 7.3. Mean self-report of Interference from noise at baseline (T1), after the short-term intervention (T2), and after the long-term intervention (T3), for each intervention group.

Error bars represent standard errors.

Finally, there is a significant difference between the sound awareness and the mindfulness groups on noise Annoyance from T1 to T3. Ratings decreased of - .27 points in the sound awareness group, but increased of .10 points in the mindfulness group – see Figure 7.4.

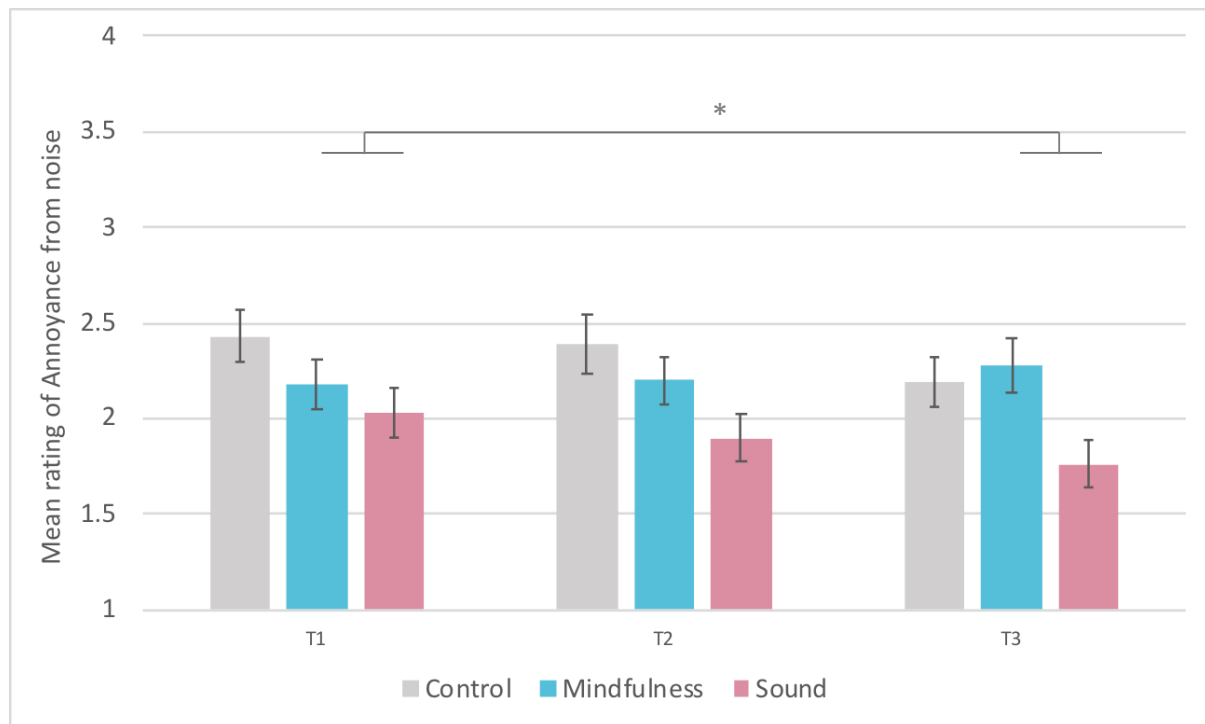


Figure 7.4. Mean self-report of Annoyance from noise at baseline (T1), after the short-term intervention (T2), and after the long-term intervention (T3), for each intervention group.

Error bars represent standard errors.

Noise levels

Since there were no missing data to handle, two repeated measures ANOVAs were carried out to test whether the change of noise levels from T1 to T2, and T1 to T3, differed between the three intervention groups. Time points (T1, T2 in the first model; T1, T3 in the second) were entered as dependent variables, and Intervention Group (control, mindfulness, sound awareness) was entered as a Fixed factor.

The first model, comparing T1 to T2, indicated a main effect of Time ($F(1, 997) = 21.72, p < .001$), but no significant interaction between Time and Intervention Group ($F(2, 997) = 0.07, p = .934$). In other words, noise levels decreased in each group between T1 and T2 (from

48.04dB to 46.42dB in the control group; from 51.62dB to 49.75dB in the mindfulness group; and from 50.23dB to 48.23dB in the sound awareness group). Figure 7.5 shows that this decrease happened in each participating class.

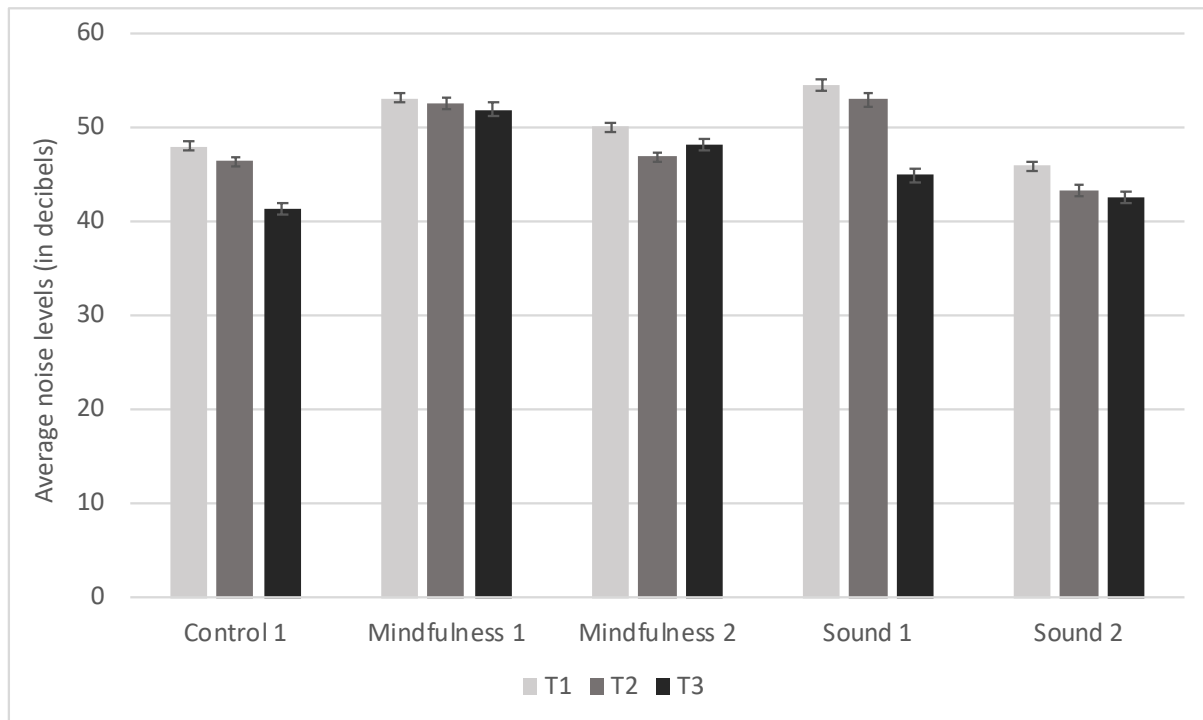


Figure 7.5. Average noise levels in each participating class, for each time point. Error bars represent standard errors.

The second ANOVA model, comparing T1 to T3, showed a main effect of Time ($F(1, 997) = 136.13, p < .001$), and a significant interaction between Time and Condition ($F(2, 997) = 19.45, p < .001$). Games-Howell post-hoc comparisons indicated that differences between the three groups were all significant at the .001 level. Follow-up paired T-test indicated a decrease in noise levels of 6.55dB in the control group ($t(199) = 8.47, p < .001$), of 1.48dB in the mindfulness group ($t(399) = 2.68, p = .008$), and of 6.42dB in the sound awareness group ($t(399) = 9.03, p < .001$). As can be seen in Figure 7.5, the reduction in noise levels in the sound

awareness group seems to be driven by the class Sound 1. Furthermore, a slight increase in noise levels can be noticed for the class Mindfulness 2.

7.2.5. Discussion

The current chapter discussed the impact of mindfulness and sound awareness interventions on classroom noise levels, children's reactions to noise, executive functions and school performance. The two interventions were compared both to each other, and to a waiting-list control group.

There was an overall decrease in noise levels over time, in each of the three intervention groups. The effect of time interacted with that of condition only when comparing the baseline noise levels with those recorded after the long-term interventions. Contrary to what was expected, the decrease in noise levels was smaller in the mindfulness group (1.48dB) compared to the sound awareness group (6.42dB) and to the control group (6.55dB). Although the reduction of 1.48dB was significant, it is quite a small difference to be perceived by pupils and teachers. Indeed, if a physical doubling in the sound energy corresponds to an increase of 3 dB, it is estimated that an increase of 6- to 10-dB has to happen for the noise to be *subjectively perceived* as twice as loud (Nathanson & Berg, 2019). In that sense, the reduction in noise levels occurring in the sound awareness and control groups is more likely to be significant in term of its impact on pupils' and teachers' well-being.

Improvements in children's reactions to noise were mostly noticed in the sound awareness group. Ratings of Interference from noise diminished in this group after the long-term

intervention, whereas they increased in the mindfulness group and stayed relatively stable in the control group. Children's feelings of Annoyance from noise also diminished in the sound awareness group, after the long-term intervention, whereas they slightly increased in the mindfulness group. These findings are again contrary to the hypotheses stating that mindfulness would be the most efficient intervention to reduce negative feelings towards noise. Mindfulness training was expected to lead to an improvement in children's executive functions, some of which (sustained attention, working memory) have been associated with children's subjective reactions to noise.

However, there were no significant differences in the evolution of executive functions between the three intervention groups. Only some *trends* could be noted ($p < .1$), and they were in the opposite direction to what was expected. Scores at the Letter Cancellation Task tended to improve in the sound awareness group after the long-term intervention, whereas they diminished in the mindfulness group. The same phenomenon occurred for the verbal working memory task. Even if these results do not fit with the initial hypotheses, they are quite coherent with the changes in children's reactions to noise. Chapter 5 showed that stronger feelings of noise interference were associated with lower verbal working memory. Here, feelings of noise interference decreased in the sound awareness group compared to the mindfulness group, whereas verbal working memory increased. Additional correlations on change scores showed that improvements in working memory from T1 to T3 were associated with a reduction in Interference from noise ($r = -.33$; $p = .008$)¹⁴. It is possible that

¹⁴ This correlation was calculated across the entire sample, since filtering procedures for the working memory test and missing data reduced the sample size to 24 when comparing T1 and T3 scores *within* the sound awareness group.

the sound awareness intervention impacted on both working memory and feelings of interference, when compared to the mindfulness intervention.

However, it is unlikely that changes in Annoyance were related to changes in executive functions (no association has been found between these two sets of measures in Chapter 5). Noise annoyance is more likely to be related to other factors, such as children's attitudes toward the source of noise. In particular, noise annoyance is more likely to occur when the source of noise is perceived as out of control (Stallen, 1999). The sound awareness intervention highlighted children's responsibility in the generation of noise, by checking noise levels with sound level meters, and regulating noise using visual panels. That might have been the key ingredient that was lacking in the mindfulness intervention.

The mediation exercises that were proposed through audio files might have trained children to be more aware of their sensory experiences, explaining why they reported that noise interfered more with their activities in class, after the long-term intervention. But the mindfulness intervention might not have been very efficient in teaching children how to regulate noise. Body exercises, which might lead children to be aware of and to control their behaviour, were only included in the short-term part of the intervention, after which there was actually a marginal improvement in response inhibition compared to the control group. Body exercises were not included in the long-term intervention because they require the presence of a trained expert. It is possible that a more sustained practice on this component of the intervention would have improved response inhibition and diminished noise levels.

The lack of improvement in executive functions should be put in perspective with the opposite results from Biegel and Brown (2010) and Napoli et al. (2005). The design of these two studies was less stringent than the one adopted here. Biegel and Brown (2010) did not include a control group, and Napoli et al. (2005) did not provide measures of baseline performance for each group. Furthermore, it is possible that testing sessions were planned very shortly after the mindfulness practice – although these details are not provided in the papers. Adult studies reporting an improvement in executive control tested participants *immediately* after their last training session (Tang et al., 2007; Wenk-Sormaz, 2005). In the current study, post-testing at T2 started on a Monday, so three days minimum after the last mindfulness workshop (happening on a Friday). The time lapse between the second post-test assessments (T3) and the last practice in class varied depending on how the teachers implemented the interventions, but one of them stopped practicing for two weeks before testing. Any changes in executive functions might not have been sustained over such a period of time. It should be kept in mind that the timing of the testing periods might help to understand the discrepancies between the present findings and what has been reported in the mindfulness literature. However, it does not help to understand the differences between the mindfulness and the sound awareness groups in the current study, since similar time lapses were noticed in this group.

Given that the mindfulness intervention did not have a strong impact on response inhibition, noise levels, or executive functions, improvements in reading comprehension in the mindfulness group are hard to interpret.

To summarise, this study suggests that the sound awareness intervention is more promising than the mindfulness intervention, when it comes to the generation and perception of noise levels in class. This might be due to the specificity of the training, that empowered teachers and pupils to be more aware of, and to regulate noise levels. Note that most of the differences that were identified in the statistical tests occurred between the sound awareness and the mindfulness groups, not between each of these groups and the waiting-list control. This makes results difficult to interpret. However, the fact that noise levels diminished in the control group without being accompanied with a reduction in feelings of noise interference indicated that physical changes are not enough to induce a change in pupils' reactions to noise.

The limitations of the current study should also be kept in mind. The sample size in each intervention group was small, and the two classes that formed each intervention group varied in the way they implemented the long-term interventions. Furthermore, noise levels were collected in the absence of the Experimenter. This was to avoid influencing children's and teachers' behaviour, by making the measurement highly visible. However, in the absence of the Experimenter, it was difficult to understand which activities the children were engaged in at the time of measurement. Different activities (e.g. individual work, group work, group work with movement) generate different noise levels (Shield & Dockrell, 2004). However, because the main issues surrounding classroom noise are about its interference with children's independent work, as well as with teacher-pupils communication (Dockrell & Shield, 2006; Klatte et al., 2013; Shield & Dockrell, 2003), it is important to take into account the noise generated by both the pupils and the teachers, in a variety of situations.

Despite its limitations, the strengths of the present study should be highlighted. In particular, behavioural and self-report measures have both been used, to provide a more complete assessment of children's executive functions and perceptions of their classroom environment. As such, this study extends the available evidence on both mindfulness and sound awareness interventions. Furthermore, short-term interventions, carried out by experts, were combined with a long-term intervention led by the teachers themselves. Results showed that differences between T1 and T3 were stronger than between T1 and T2, suggesting the importance of empowering teachers with the intervention material, and of giving enough time for the changes to be implemented. Here, the sound awareness interventions seemed more promising to help children cope with classroom noise.

Chapter 8 will put these results in perspective with those of the previous chapters, in order to provide an overview and discussion of the overall thesis.

Chapter 8 - General discussion

8.1. General overview of the thesis

This thesis aimed to understand better why, in primary schools, some children are more affected by classroom noise than others. Both the impact of noise on task performance, and on children's subjective reactions to noise were investigated. Both of these issues are important if one is concerned with both children's learning outcomes as well as their wellbeing. The present chapter will summarise and discuss the main findings of the thesis. Some limitations of the present work will be pointed out, and suggestions for future research will be made.

8.2. Summary and discussion of the main findings

8.2.1. Inter-individual differences in the impact of noise on performance

Two types of noise were considered because they have been identified as the main sources of noise children are exposed to in their classroom (Boman & Enmarker, 2004; Shield & Dockrell, 2004): verbal noise (e.g. single-talker speech), and mixed noise (e.g. noise combining verbal noise, noise coming from movement, and/or transportation noise).

Experimental studies on children (see Table 1.1. for a review) indicated that moderate (50 to 70dB) verbal noise has a detrimental impact mostly on attention (Dockrell & Shield, 2006), memory (Elliott, 2002; Elliott & Briganti, 2012; Klatte et al., 2007, 2010), and some verbal tasks (Boman, 2004; Dockrell & Shield, 2006), but not necessarily on mathematics (Kassinove, 1972). In contrast, mixed noise has been shown to affect attention and memory negatively

(Dockrell & Shield, 2006; Klatte, Lachmann, Schlittmeier et al., 2010), but to have either a non-significant or even a positive impact on reading and mathematics (Dockrell & Shield, 2006; Ljung et al., 2009; Slater, 1968).

Inter-individual differences in the effect of noise have been investigated in adults, but not in children. Adult studies have indicated that two executive functions (often conflated) might mediate the impact of noise on learning: working memory (the ability to store and manipulate information that is no longer present), and the inhibitory control of attention (the ability to choose what to attend to, and to filter out unwanted stimuli; Sörqvist, 2010b; Sörqvist, Halin, & Hygge, 2010; Sörqvist, Ljungberg, & Ljung, 2010). A closer look at these studies suggested that inhibitory control could be the main factor mediating the impact of noise. Crucially, inhibitory control could act both as a protective factor against the negative effect of noise on performance (e.g. in the case of verbal noise), but also as an explanatory factor for the positive impact of mixed noise on performance. Indeed, it has been suggested that noise impacts task performance by redirecting participants' attention, a mechanism that could be detrimental for low-level tasks involving sustained attention, or short-term memory (Dockrell & Shield, 2006; Klatte, Lachmann, Schlittmeier, et al., 2010; Zentall & Shaw, 1980), but beneficial for higher-level tasks involving abstract processing and idea generation, such as creativity (Mehta et al., 2012) and comprehension tasks.

By directly measuring primary school children's working memory and inhibitory control, while comparing their performance in silence and noise, the present thesis aimed to test whether the impact of noise is mediated by attentional processes. To provide consistency in the age

range of participants, all the studies from this thesis included children in their late primary school years.

In Experiment 1 (Chapter 2), 8.82- to 11.40-year-old children were tested in silence (35-45dB), or in noise. The noise consisted in either moderate (65dB L_{Aeq}) verbal noise, or moderate (65dB L_{Aeq}) mixed noise. Reading comprehension, text recall, and mathematics performance were assessed. Noise only had a negative impact on tasks involving a salient memory component; that is to say, text recall and mathematics. There were order effects: performance in noise being worse than in silence, but only when participants were tested in the noisy session first. Crucially, there was no significant difference between the impact of verbal and mixed noise. This was surprising, in light of the existing literature, but could be due to the fact that the two types of noise contained some phonological information, and were characterised by similar fluctuations in sound pressure level, which could have had the potential to capture children's attention.

Additional mediation analyses, showed, however, that the impact of noise was not mediated by inhibitory control, as measured with a Flanker task. Verbal working memory did play a role in explaining inter-individual differences in the effects of noise on mathematics performance: the impediment due to noise tended to be smaller for children with higher working memory. The working memory task (the backward digit span task) involved remembering a series of digits and recalling them backwards. As such, it shared processes and content with the mathematics task, which also involved the manipulation of digits in short-term memory (e.g. to perform additions or subtractions). In that sense, better working memory, overall, predicted better mathematics performance, whether it was tested in silence or in noise.

However, what is crucial here is that working memory also partly predicted the *difference* in performance between the silent and noisy sessions. According to Baddeley's (2003) model of working memory, a phonological loop helps to keep information in mind by sub vocally rehearsing it. In Experiment 1, both the phonological information from digits, and from the background noise could have gained access to the phonological loop, interfering with each other. Results from Experiment 1, therefore, provide more evidence for phonological accounts of noise interference effects than attentional accounts. The putative mechanisms at play, however, seemed very specific to the task at hand. For example, there was no mediation by the backward digit span of performance on the text recall task, which involved the manipulation and understanding of words (not of digits).

Experiment 2 (Chapter 3) was based on a broader age range (from 4.95 to 11.36 years of age). Children in their early primary school years (up to 8 years of age) were distinguished from children in their late primary school years (above 8 years of age). Children were tested on two idea generation tasks, both in silence or with 64.3dB L_{Aeq} of background noise. Children's inhibitory control (Stroop and Flanker tasks), verbal working memory (backward digit span task), and visuo-spatial working memory (Corsi block task) were assessed. As in Experiment 1, children in their late primary school years were not affected by noise. However, children in their early primary school years had lower originality scores in noise compared to silence for one of the two idea generation tasks.

Inhibitory control, but not working memory, mediated the impact of noise on performance. Whatever their age, children with low inhibitory control (e.g. who were experiencing interference in the Flanker task) gave ideas that were less original in noise, as compared to

silence. Children with high inhibitory control (e.g. who were resistant to interference in the Flanker task) performed similarly in silence and noise. Crucially, a younger age and a low inhibitory control constituted cumulative risk factors when performing an idea generation task in noisy conditions: younger children with low inhibitory control were the most impaired. All the effects in Experiment 2 occurred for only one of the two idea generation tasks – the one which involved more narrative processing. In terms of mechanisms, and contrary to Chapter 1, Experiment 2 provided more evidence for the attentional account of noise interference, than for the phonological account.

Overall, results from Chapters 2 and 3 indicate that, in line with the literature, moderate classroom noise is not systematically bad for learning. For children in their late primary school years, noise mostly had a negative impact on tasks involving a salient memory component; that is to say, text recall and mathematics. Reading comprehension and idea generation were not affected. There was no situation in which children benefitted from noise (e.g. performed better in the presence of noise). As such, the finding of adults showing better performance at an idea generation task in conditions of moderate mixed noise could not be extended to a child population (Mehta et al., 2012). Some risk factors could, however, be identified. These were specific to the task at hand. Children with low working memory were more impaired by verbal and mixed noise when engaged in a mathematics task, and children with low inhibitory control were more impaired by mixed noise when engaged in an idea generation task. Furthermore, when assessed on an idea generation task, children in their early primary school years were more vulnerable to moderate mixed noise than their older peers, especially if they had low inhibitory control skills.

Three main theories have been proposed to account for the impact of noise on performance. According to the order processing account, noise that can be segmented and “ordered” interferes with the processing of order in the task at hand. The phonological/semantical account, in contrary, put the emphasis on the content, not the structure of the noise. Noise containing phonological and/or semantic information (e.g. speech) would interfere with the processing of phonological and/or semantic information in the main task. Finally, the attentional account posits that noise impacts performance by deviating attention away from the task at hand, which could have a negative impact on focused tasks, but also some positive effects on abstract thinking and idea generation.

Most of the theories investigating the cognitive mechanisms underlying noise interference have previously been discussed and tested within the context of memory tasks, and more specifically, serial recall tasks (Elliott & Briganti, 2012; Jones, Macken, & Murray, 1993; Salamé & Baddeley, 1982; Sörqvist, 2010b). The present thesis used a broader range of tasks that are more representative of what is expected from pupils in school settings. Experiment 1 provided some evidence for the phonological account of noise interference, because verbal working memory interacted with the impact of noise on mathematics. Both the noise and the mathematic task are thought to rely on the maintenance of phonological information in working memory. Experiment 2 provided some evidence for the attentional account of noise interference, because inhibitory control interacted with the impact of noise on idea generation. The lack of systematic interactions between the effect of noise and executive functions, across all tasks, suggests that the mechanisms underlying any observed effect of noise on performance may indeed be task-specific.

Experiment 1 and Experiment 2 were the first ones to directly test the role of executive functions when working in noisy conditions, in primary school populations. These studies focused on behavioural assessments. Children's subjective reactions to noise were assessed via a single question ("How distracting did you find the noise coming from the headphones / speaker?"). The children's answers did not align with the actual impact of noise on their performance, nor with the children's executive function performance. This prompted further investigations aiming to understand better children's reactions to noise, and the relation between these reactions and attentional processes.

8.2.2. Inter-individual differences in children's subjective reactions to noise

Chapter 4 presented the results of a school survey assessing children's reactions to noise in their classroom environment. Five dimensions were extracted in children's answers, indicating to what extent they: 1) found their classroom noisy; 2) reported hearing difficulties; 3) noticed noise when engaged in learning activities; 4) lost track of their ongoing activity because of noise; 5) were annoyed by noise. The last two dimensions (noise interference and noise annoyance) were used as the main outcome variables in further analyses. Indeed, theoretical and empirical evidence on adult populations suggested that noise interference and noise annoyance might be underpinned by different mechanisms, although they have often been confounded under the broad construct of "noise sensitivity" (Job, 1999). Noise interference would reflect cognitive, attentional processes, whereas noise annoyance would be based on emotional attitudes and judgments (Stallen, 1999).

Chapter 4 started to investigate inter-individual differences in noise interference and noise annoyance by testing to what extent these dimensions were predicted by self-reported measures of hearing difficulties, switching skills, and mind-wandering. Children reporting more difficulties to hear in the classroom also reported more interference and annoyance from noise. The effect on noise annoyance was not mediated by the effect on noise interference. Hearing difficulties were assessed at a subclinical level, among a sample of typically developing children. These results were consistent with, and extended findings on children with hearing impairments showing that they are particularly vulnerable to noise (Connolly, et al. 2013; Picard & Bradley, 2001; Shield & Dockrell, 2003).

Cognitive predictors of children's reactions to noise could also be identified. Children reporting a greater propensity to let their mind-wander reported more interference, but not more annoyance from noise. This was in line with the empirical and theoretical evidence suggesting that mind wandering represents a failure of executive function processes, making it more difficult to stay on task and to ignore irrelevant thoughts and stimuli (McVay & Kane, 2010). The fact that mind-wandering did not predict noise annoyance went against the idea that mind-wandering could be a coping strategy to reduce noise annoyance by disappearing in daydreams (Boman & Enmarker, 2004).

Switching skills, contrary to mind-wandering, predicted both noise interference and noise annoyance by two separate pathways. Switching skills might allow children to stay on task despite the presence of noise, and might favour the adoption of a flexible perspective to avoid focusing and stressing too much about noise. A key limitation of Chapter 4 is that it only relied on self-report measures. Since both mind-wandering and switching skills predicted noise

interference, and were assumed to rely on executive functions processes (Diamond, 2013; McVay & Kane, 2010), a next step was to test whether behavioural tests of executive functions predicted noise interference and noise annoyance.

Chapter 5 included measures of inhibitory control and working memory previously used in Chapters 2 and 3 (a Flanker task, and a backward digit span task), as well as two assessments of sustained attention. The Sustained Attention to Response Task was included to provide a measure of reaction time variability, which has been associated with greater mind-wandering in the adult literature (McVay & Kane, 2009, 2012). The Letter Cancellation task is a paper and pencil activity that has been considered by teachers to be more representative of everyday life attentional processes than short reaction time measures derived from the Flanker task and from the Sustained Attention to Response Task. A greater reaction time variability, and a lower working memory were associated with more interference from noise. In contrast, these two skills were not associated with noise annoyance. In that respect, results were in line with those of Chapter 4, indicating that noise interference and noise annoyance might be underlined by different processes. In particular, noise interference might have more to do with cognitive (i.e. executive processes), whereas noise annoyance might involve judgments and attitudes with emotional and social components that were not included in the survey (Stallen, 1999). In line with this idea, attention capture (the tendency for children to notice noise in the classroom), was related to the same variables as noise interference (that is to say, reaction time variability and working memory). However, and contrary to what was expected, self-reports of mind-wandering and switching skills were not directly associated with executive functions. This highlights the difficulty encountered in trying to connect survey and behavioural methods.

Studies from Chapters 2 to 5 investigated the effects of noise during one-shot assessments, using scores on behavioural tasks and surveys with predefined answers. In Chapters 6 and 7, children were followed over a six-month period, before and after school-based interventions which had the potential to influence both the generation and the perception of classroom noise. In addition, naturalistic measures of classroom noise were obtained.

8.2.3. Implementing noise reduction interventions in school

Two types of interventions were implemented, the first focussed on mindfulness practice and the second focussed on sound awareness. The mindfulness practice intervention highlighted the need to train one's attention, and to adopt an open and accepting orientation toward one's experience (Kabat-Zinn, 2003). It consisted of four hours of workshops, led by an expert, followed by more long-term and regular activities in the classroom based on audio files providing meditation exercises. The sound awareness intervention was focused on the issue of noise. During four hours of workshops, children experimented with the concepts of sound and noise with an expert, and discussed the impact of noise on health. These workshops were followed by more regular and long-term activities implemented in the classroom. Visual panels indicating noise levels were installed to help children become aware of, and to regulate noise levels. Children also trained their perception of noise levels, by estimating the amount of noise generated by different classroom activities, and checking the actual value on a sound level meter.

Chapter 6 discussed the implementation of the interventions, children's feedback and self-reported changes in mood and attention while they were engaged in the long-term activities.

Two classes were involved in each intervention. These varied in the frequency with which they implemented the activities. Despite this variability, children in all classes reported that they liked the activities, found them useful, and not difficult. They indicated feeling in a better mood and having better attention after the activities, an improvement that actually slightly diminished over the course of the interventions (for both groups, when measuring attention, and only for the sound awareness group, when measuring mood). Importantly, there was great variability in children's answers from day to day: some children reported improvements in attention/mood after each moment of practice, whereas some children alternated between positive changes, negative changes and no changes depending on the day of practice.

Overall, results were consistent with previous evidence suggesting that mindfulness training might help children to regulate their mood and attention. However, it might not be the only, nor indeed best intervention, as the sound awareness intervention almost had the same effect. Relying on self-report procedures allowed to collect regular data in class, as the interventions were happening. However, results had to be reinforced with behavioural assessments in order to strengthen the evidence, and to connect these results with those from previous chapters.

Chapter 7 reported on a selection of executive function measures that were used in previous chapters, and that were collected before the start of the interventions, after the four hours of workshop, and at the end of the school year (following 10 weeks of practice in class). Working memory was assessed with a backward digit span task, inhibitory control with a Flanker task, sustained attention with the Letter Cancellation task and the Sustained

Attention to Response Task. Self-report measures of switching skills and mind-wandering were included to favour comparisons with previous chapters. Crucially, to test whether the interventions were associated with changes in the generation and perception of classroom noise, noise levels were recorded in the participating classrooms and children's reactions to noise were assessed with the same questionnaire as used in previous chapters.

Only the sound awareness intervention was associated with a change in both the generation and perception of noise. A reduction from 50.23dB to 43.81dB was noticed, and children reported less interference and less annoyance from noise following this intervention. These changes were not accompanied by changes in children's executive functions, switching skills, or mind-wandering. There was only a trend towards improvements in sustained attention and working memory, which, based on the previous chapters, could be associated with the changes in noise interference.

Similarly, and contrary to expectations, mindfulness practice did not have a significant impact on children's executive functions. Improvements in reading comprehension were identified, but these were difficult to interpret. A reduction in noise levels from 51.62dB to 50.14dB was also found, which was significant, but unlikely to impact on children's wellbeing, given that an increase of 6- to 10-dB has to happen for the noise to be *subjectively perceived* as twice as loud (Nathanson & Berg, 2019).

Sound awareness interventions are therefore more promising as a means of helping children to regulate noise levels, and to reduce negative reactions to noise. These interventions provide children with information about sound and noise, while also implementing tools that

they can use in their everyday life to be better aware of noise. Indeed, visual panels displayed on the classroom's wall act as a constant prompt and reminder to pay attention to noise. Most of the intervention effects were noticed after the long-term component of the interventions, which corresponded to teacher-led activities in class. This highlights the importance of giving enough time for the changes to be implemented, and of empowering teachers with the ability to use the materials flexibly in class. The mindfulness intervention seems less promising when it comes to dealing with classroom noise. Mindfulness represents a state of mind and an attitude that have to be regularly, and consciously activated to produce benefits (e.g. stress reduction, better attention, etc.). Children might have difficulties entering a mindful mindset on their own in everyday life. In experimental studies, positive effects of mindfulness training might be mostly observed when the effects are assessed straight after the practice.

8.2.4. A possible model of the effects of noise

Results from the experimental, survey, and intervention studies were combined to form the model represented in Figure 8.1.

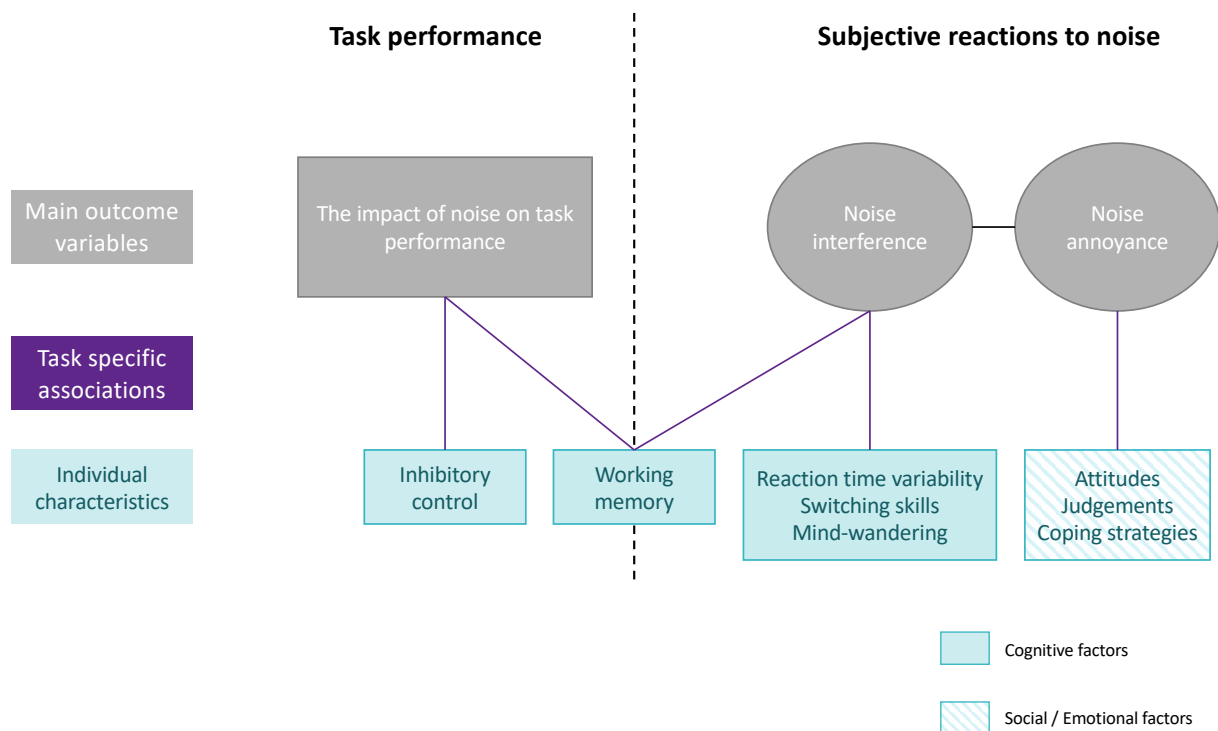


Figure 8.1. Model integrating the impact of noise on: 1) task performance, and 2) children’s reactions to noise, as influenced by children’s individual characteristics.

The two main lines of inquiry of this thesis [1) the impact of noise on task performance, and 2) children’s subjective reactions to noise] are depicted on the left-, and right-hand-sides of the figure respectively. In the model, these two aspects are not directly connected to each other, because: 1) In experimental studies, children’s feelings of distraction from noise did not correspond to the actual impact of noise on their performance; 2) Different executive processes explained inter-individual differences in the impact of noise on performance and in children’s reactions to noise; and (3) In-class interventions leading to changes in noise levels and in children’s reactions to noise did not necessarily lead to similar changes in school performance. In addition to the cognitive processes that have been measured in this thesis (inhibitory control, working memory, reaction time variability, sustained attention, switching and mind-wandering), individual characteristics that are thought to influence children’s

annoyance reactions, such as judgements, attitudes, and coping strategies, have been added. The model depicted in Figure 8.1. can therefore be compared to the models proposed by Boman and Enmarker (2004), Guski (1999) and Stallen (1999), represented in Figures 8.2, 8.3, 8.4, respectively.

Boman and Enmarker (2004) focused on middle school pupils' reactions to noise. They proposed a serial model in which general sensitivity to noise predicts children's adaptation to noise, which predicts their annoyance feelings, and, in turn stress symptoms. We suggest that using a factor of general sensitivity to predict annoyance reactions is tautological, since noise sensitivity reflects the tendency to react more strongly to noise *in general*, when annoyance reflect negative feelings toward a particular source of noise (Belojevic et al., 2003). As such, noise sensitivity does not constitute an explanatory factor in itself. However, Boman and Enmarker's (2004) general sensitivity factor contained an item about hearing sensitivity, which we have also shown to be related to feelings of noise annoyance. Boman and Enmarker (2004)'s adaptation factor reflects speech comprehension problems due to noise. In our studies, speech comprehension problems were included in the measure of noise interference, which was correlated with noise annoyance. However, it would be interesting to see whether Boman and Enmarker (2004)'s noise adaptation factor would differentially predict children's cognitive (e.g. difficulties to concentrate) and emotional (e.g. irritation) reactions to noise, as both are included in their annoyance factor. Our work points to the need to dissociate cognitive and emotional reactions to noise. Finally, the impact of classroom noise on stress, which has been measured by Boman and Enmarker (2004) but not in the present thesis, should also be kept in mind.

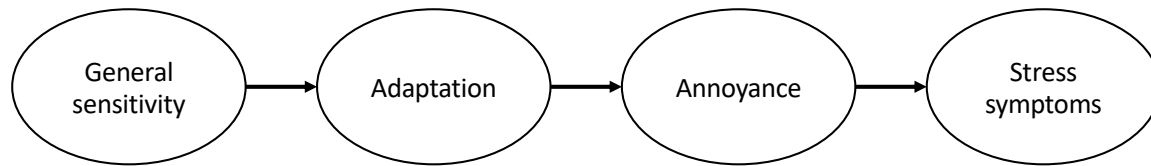


Figure 8.2. Boman and Enmarker (2004)'s model of middle school pupils' reactions to noise

Guski's (1999) model expressed the impact of environmental noise on adults' living conditions, an approach that is quite different than ours. They specified a general factor of noise disturbance / annoyance as a long-term consequence of exposure to environmental noise. We suggest that it is important to dissociate noise disturbance (that we called "interference") and noise annoyance. Furthermore, Guski (1999) drew a direct link between the short-term interference caused by noise on everyday life activities (e.g. communication, sleep), and participants' reported disturbance and annoyance. This link might not be so direct when considering the impact of noise on task performance, as was the case in the present thesis, or in laboratory studies with adults.

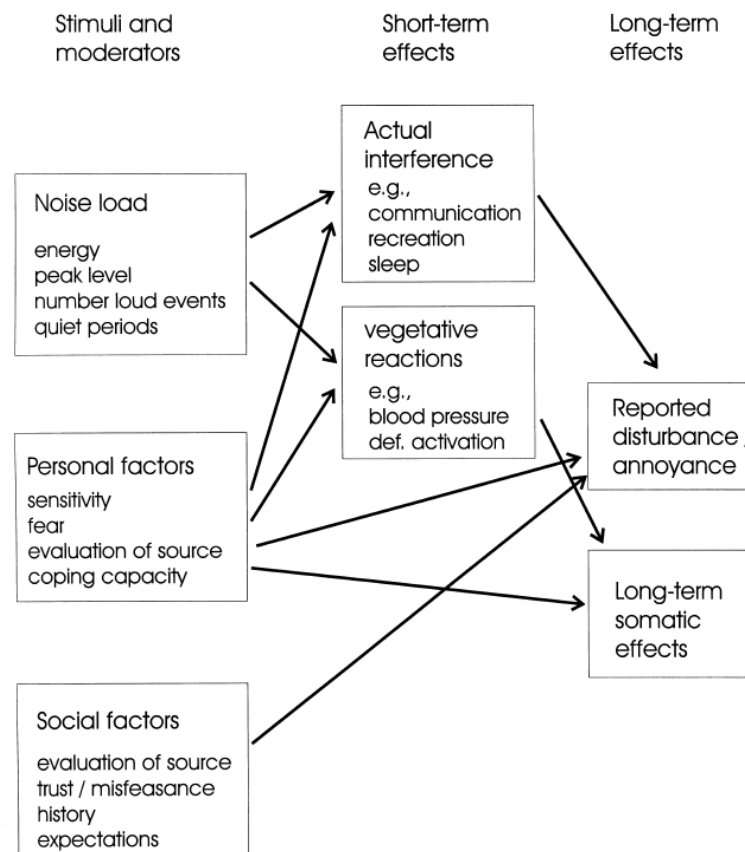


Figure 8.3. Guski (1999)'s model of short-term and long-term reactions to environmental noise

Our model is closer to that of Stallen (1999), who dissociated noise disturbance and noise annoyance, while suggesting factors influencing annoyance, but not disturbance (e.g. perceived control, or the capacity to cope with annoyance). Our work complements this approach by suggesting factors that might influence noise disturbance (that we called “interference”), but not noise annoyance. Among these are attentional processes (measured by reaction time variability in a sustained attention task) and working memory processes.

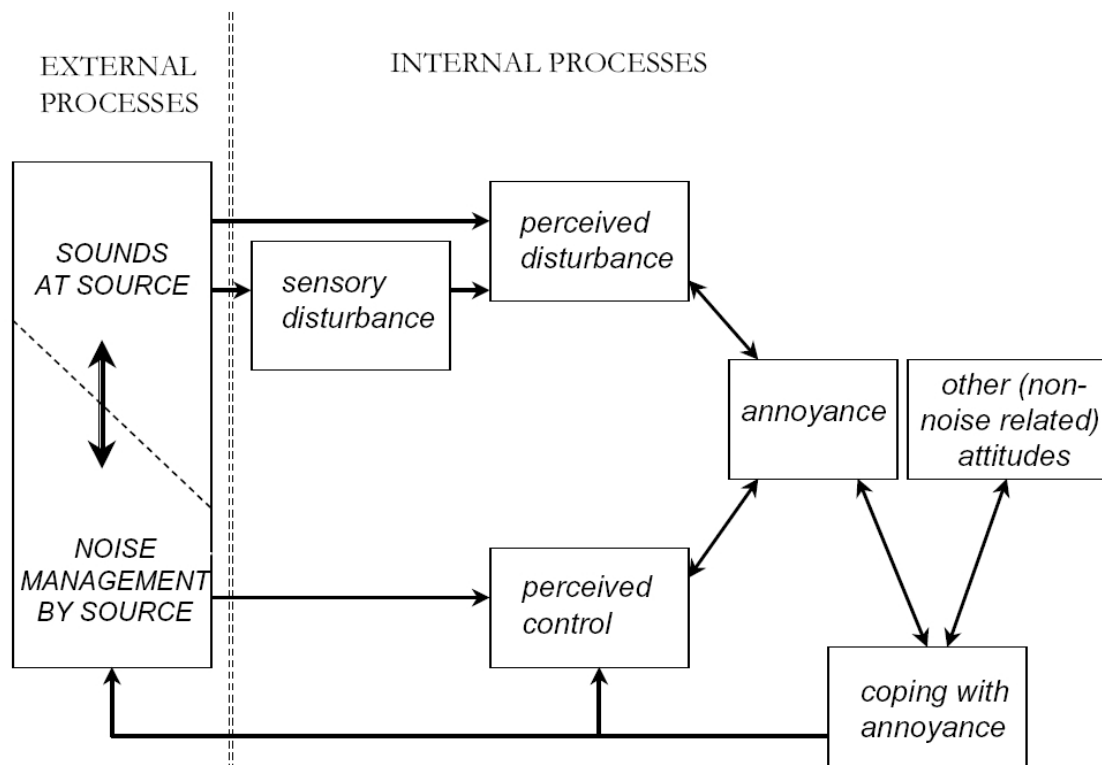


Figure 8.4. Stallen (1999)'s model of reactions to noise

8.3. Limitations and future research

The present thesis used a variety of methods to better understand the role of executive functions in explaining the impact of noise on task performance, and children's subjective reactions to noise. These methods were represented throughout the thesis by a two-dimensional diagram placed at the beginning of each chapter. Figure 8.5. summarises the different approaches that have been taken. It should be noted that both proximal and distal factors that are thought to influence learning outcomes have been addressed (Thomas, Ansari & Knowland, 2018): child factors (e.g. attentional and memory resources), school factors (e.g. the classroom environment) and government factors (e.g. the new school interventions took

into account teachers' needs and the education budget to complement the existing curriculum).

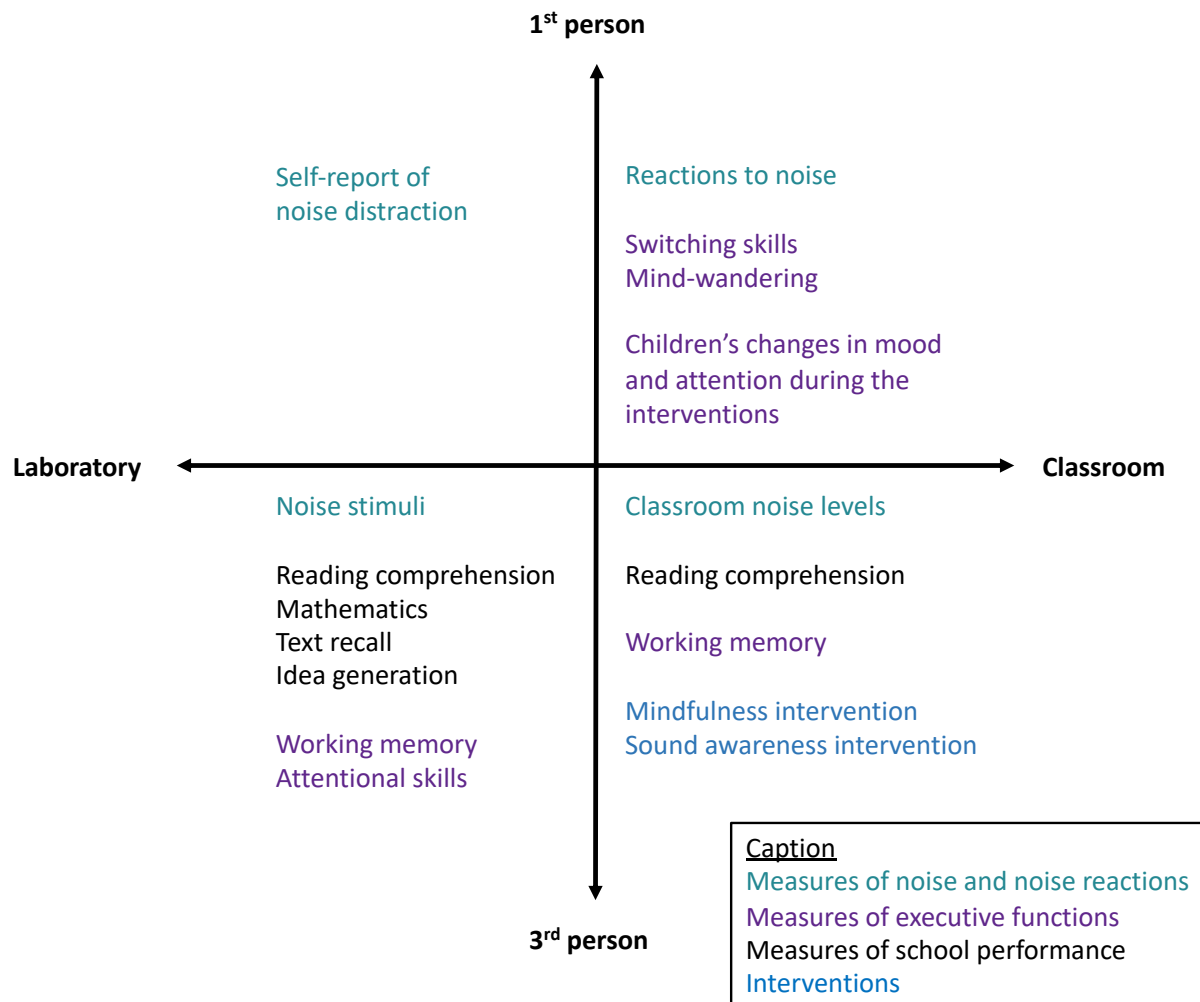


Figure 8.5. Diagram summarising the methods used in the thesis

Areas of development for future research can also be pointed out.

First, it can be noticed that a broader range of school tasks has been included in the laboratory studies, as compared to the in-class study. Furthermore, whereas recorded noise stimuli were used in laboratory studies, and carefully controlled for, this was not the case in the in-class study, where only the noise levels, not the content of the noise, were measured. Several

experiments in the literature generated artificial noise while testing children in their usual classroom (Hygge, 2003; Ljung et al., 2009). To our knowledge, there has been no study directly comparing the impact of a given type and level of noise, when children are engaged in individual work in controlled settings (e.g. laboratory settings), and when they are in their usual classroom. Such studies would be methodologically challenging (since there would be a need to control for practice and habituation effects), but would help to bridge the gap between the two strands of the literature.

Second, the self-report measure of noise distraction used in the laboratory studies reported in Chapters 2 and 3 was quite simple and limited to a single question (“How distracting did you find the noise?”). The use of more complete assessments, including both cognitive, and emotional reactions to noise (as have been identified in the school survey) would be useful. This would help to better understand how children perceive the impact of noise on their performance and well-being, and how this relates to the impact of noise on specific tasks (e.g. attention, memory, school performance). Here, to allow for comparisons with previous studies (i.e. Hygge, 2003; Slater, 1968), it would be interesting to see whether the impediment in attention and memory caused by noise relates to children’s feeling of interference and annoyance from noise. In other words, attention and memory could be incorporated not only as potential mediators between the impact of noise on school performance, but as outcome variables themselves, that are impacted by the presence of noise.

Third, additional mediators can be considered when trying to explain inter-individual differences in the effect of noise on both task performance and children’s reactions to noise. The present thesis focused on attentional processes and on working memory because these

were proposed as two main mechanisms explaining noise interference in previous published theoretical and empirical studies. However, attentional processes were measured via the *visual*, and not the auditory modality. For example, in the Flanker task, children saw a row of fish on the screen, and had to indicate the direction the middle fish was pointing to, when it was surrounded by fish pointing in the same direction, or in the opposite direction. Working memory was assessed in a visual way in Chapter 2 (children saw a list of digits and had to repeat them backward), but also via the auditory modality in Chapters 3, 5 and 7 – here children heard lists of digits. Working memory interacted with the impact of noise on mathematics, in Chapter 2, but not with the impact of noise on idea generation in Chapter 3. Therefore, it is not the case that working memory was a stronger predictor of the effects of noise when it was assessed auditorily. However, it would be worth including measures of auditory *selective attention* in future studies (Conway et al., 2001) and to test what children remember from the irrelevant noise. This would help to better understand how the irrelevant noise is processed and/or filter out by children when they are engaged in school tasks.

More generally, the lack of strong and systematic correlations between self-report and behavioural measures of executive functions deserves further exploration. This phenomenon has been noticed elsewhere in the literature (Toplak, West, & Stanovich, 2013), and shared in various conferences that were attended during the development of this thesis (e.g. EARLI SIG 22 Conference 2018, International, Mind, Brain and Education Conference, 2018). This lack of correlation makes it hard to connect evidence from experimental, laboratory-based studies, with that arising from naturalistic, school-based research. Indeed, if one wants to reach a high number of pupils efficiently, while gaining information on their behaviour in class, questionnaire measures, filled by the pupils and/or teachers are much easier to use.

However, in the experimental literature, behavioural assessments of executive functions are privileged. These assessments are usually carried out during a single-shot assessment, in controlled conditions and under the supervision of an experimenter who defines the rules of the task. Questionnaire measures, on the other hand, assess children's behaviour in a variety of everyday life settings and self-driven activities, which involve cognitive, but also social and emotional factors.

To bridge the gap between these two strands of research, behavioural measures of children's attentional processes in real-life settings could be implemented. These would provide objective measures, but placed in context. For example, Godwin et al. (2016) observed children's on- and off-task behaviour in the classroom. Children's behaviour was considered as on-task if they were looking at the teacher, the instructional activity and/or the relevant instructional materials. If children were looking elsewhere, their behaviour was coded as off-task. Off-task behaviour could refer to self-distraction, peer distraction, environmental distraction, walking, or other types of behaviours. The coding system took into account the overall educational context and teachers' instructions. It therefore provided a balance between the need to have objective measures, and the need to take the context into account. However, in the case of distraction caused by noise, such a system would prove challenging to implement because there are no systematic overt cues indicating whether children have processed a specific sound stimulus or not. The use of portable electroencephalograms, which is increasingly common in educational research (Xu & Zhong, 2018), might help to track sound processing in everyday life contexts (Debener, Minow, Emkes, Gandras, & De Vos, 2012), although it still reveals methodological challenges.

Furthermore, in between classic “piecemeal” laboratory research and naturalistic real-world research, Matusz, Dikker, Huth, and Perrodin (2019) have suggested a third type of approach. It consists in naturalistic laboratory research, which emulates the variability present in real-world context, yet keeps it under control. This type of research would help to situate auditory distraction research in the context of multi-sensory learning, where both visual and auditory distraction interact to predict learning outcomes (Broadbent et al., 2018; Broadbent, White, Mareschal, & Kirkham, 2018; Matusz et al., 2015). Two types of variables would be worth manipulating when investigating the impact of noise on performance: the relevance of the auditory information for the task at hand, and the task’s difficulty (Matusz et al., 2015). In the present study, the focus was put on sounds that were, by default, defined as irrelevant for the on-going task, and therefore categorised as noise. However, in the classroom, useful pieces of information are sometimes included within the overall background noise. For example, a child might over-hear a conversation between peers, or between a child and the teacher that includes crucial information about how to perform the homework. Filtering out the background conversations might help to focus on the task when it is off-topic, but could lead children to miss some learning opportunities as well. Therefore, experimental studies could include sound stimuli that contain a mix of relevant and irrelevant information, while investigating how children’s auditory selective attention might help them to sort the wheat from the chaff. Indeed, according to the author Bella Bathurst, who experienced life both as a deaf and as a hearing person: “True hearing edits all the time. Every second of everyday it judges and discards, picking through what it understands to be significant and ignoring everything else” (Bathurst, 2018; p. 44).

8.4. Concluding comments

The studies from this thesis were the first to assess the role of executive functions in explaining: 1) the impact of classroom noise on children's task performance, 2) children's subjective reactions to noise. Using a stringent within-subject design, two experimental studies showed that, across children, moderate classroom noise was not necessarily bad for task performance. Impairments were mostly noticed for tasks involving a salient memory component. Executive functions partly interacted with the impact of noise. Children with low working memory were more impaired when performing a mathematics task, children with low inhibitory control were more impaired when performing an idea generation task. These results show the need to directly assess the cognitive mechanisms that are suggested to drive the developmental effects of noise on task performance (Elliott & Briganti, 2012; Klatte, Lachmann, Schlittmeier, et al., 2010), since these mechanisms are likely to be task-specific. When considering children's subjective reactions to noise, feelings of distraction and interference from noise were associated with lower executive functions (e.g. greater reaction time variability and lower working memory). However, executive functions did not predict reactions of annoyance. In an attempt to connect lab-based research with naturalistic, school-based research, classroom interventions aiming at influencing the generation and perception of noise were implemented. Sound awareness interventions are especially promising when it comes to reducing classroom noise, and ameliorating children's reactions to it. Since it is a participatory approach, it takes into account the learning context and it empowers children and teachers to regulate noise levels when they are the most disturbing. This intervention study highlighted key challenges when doing translational research, which we hope to be useful for future Mind, Brain and Education projects

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APPENDICES

Appendix A

School Tasks in Experiment 1

A.1. Mathematics

“In this activity, we are going to do some maths. You will be presented with short questions.

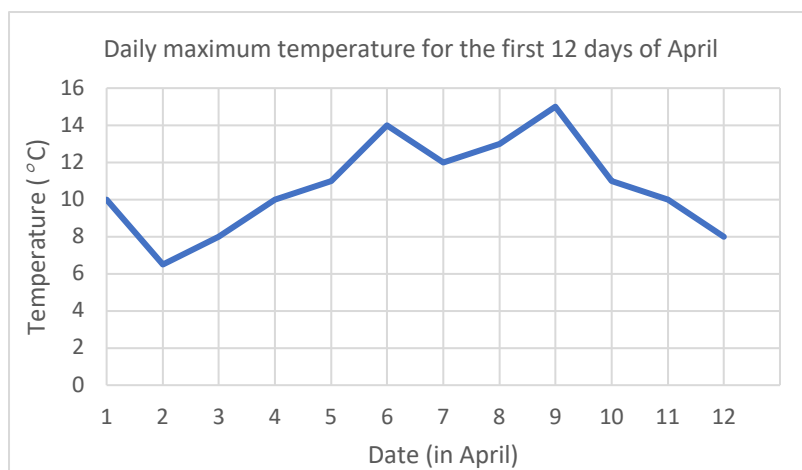
You can provide your answers using the keyboard”.

A.1.1. Session A

Statement	Answer
1. $85 - 67$	18
2. What would be the new time if the hour hand of a clock turns 180° from 9 o'clock?	3
3. $730\,822 - \dots = 330\,822$	400 000
4. 2 weeks 4 days = ... days	18 days
5. $8334 + \dots = 8634$	300
6. $23\,000 / 10$	2 300
7. $60 / 4$	15
8. 9 mm = ... cm	0.9
9. $2.3 + 0.75$	3.05
10. 14×18	252
11. 1 = ... quarters	4

12. On which day was there the highest temperature?

9th

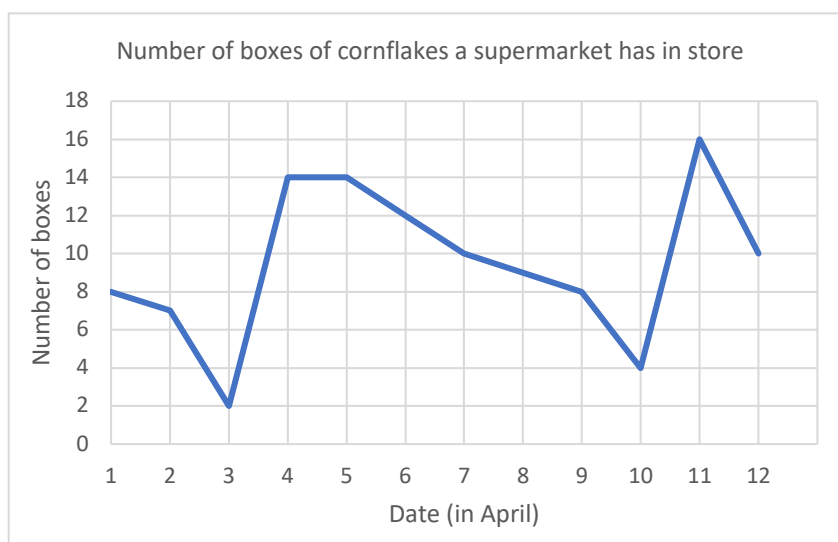


A.1.2. Session B

Statement	Answer
1. $96 - 58 =$	38
2. What would be the new time if the hour hand of a clock turns 90° from 3 o'clock?	6
3. $130\,720 - 130\,120$	600
4. 2 years 8 months = ... months	32
5. $6\,208 + \dots = 8\,208$	2\,000
6. $12\,000 / 100$	120
7. $51 / 3$	17
8. 300 m = ... km	0.3
9. $3.4 + 0.63$	4.03
10. 12×15	180
11. 1 = ... third	3

12. On which day was there the highest number of boxes in stock?

11th



A.2. Text recall

“In this activity, you will have 4 minutes 30 seconds to read a text. Then, you will be asked 6 questions. You will have 30 seconds to answer each of them. You can provide your answers using the keyboard. Spelling is not taken into account, as long as I can understand what you mean!”.

A.2.1. Session A

Long ago there lived a great prince in Wales called Llywelyn. The thing he loved best in the whole world was to play with his young son. He liked to throw the baby up into the air and hear him shout with laughter. His second favourite thing was hunting. He used to ride out of his castle at sunrise astride his prancing horse, leading his pack of hounds, as the huntsman sounded his horn and the deer bounded ahead over the frosty ground to escape.

One day, when the scent of the deer was strong and the dogs were restless for the chase, Llywelyn decided to hunt. He called his huntsmen, mounted his horse and looked over the

hounds who were barking joyfully and straining their leashes. He frowned. Gelert, the Prince's favourite hound, was not there.

"Where's Gelert?" he demanded.

No one could answer. No one had seen the great dog since the day before.

"We'll have to go without him", said Llywelyn, a frown creasing his forehead. He spurred his horse forward, unwilling to delay the hunt.

At the end of the day, the huntsmen trotted back to the castle proudly bearing a pair of fine stags. The hunt had been a great success. As they approached the castle, Gelert came limping out. Llywelyn stared down at him in dismay... Llywelyn leaped down from his horse and ran inside. A terrible suspicion made his heart pound with fear. Whose blood was smearing the dog's coat, and staining his knife-sharp claws?

"My son! Where's my son!" he shouted. He raced to the cradle where his son should have been lying peacefully sleeping. There was no sign of the child. The cradle was turned upside down, and it was clear that a terrible struggle had taken place.

"You devil! You murdering friend!" roared Llywelyn, and raised his dagger.

Gelert looked up at him one last time, his eyes filled with grief and shock, and died.

Then Llywelyn heard a little cry. He lifted up the cradle, and there, quite unharmed, lay his son, holding up his arms joyfully to his father. Beside him lay the body of a gigantic wolf. The creature's skin was scored by the marks of a hound's claws, and deep bites scarred its face.

"Oh, my faithful Gelert, what have I done?" cried Llywelyn. "You have saved my son's life, and I killed you for it!"

He carried Gelert's body out of the castle, and buried it in a place where all who passed by could see it and learn the story of the faithful hound. A pile of stones was set over the place where Gelert lies, and the castle was renamed Beddgelert, which means, the Grave of Gelert.

	Question	Answer
1.	What does Llywelyn love the best? (l. 2)	Playing with his son Playing with his baby
2.	What is the second thing Llywelyn loves the best? (l. 3)	Hunting
3.	Who is Gelert? (l. 9)	Llywelyn's favourite hound Llywelyn's favourite dog A dog A hound
4.	What did the huntsmen bring back from the hunt? (l. 14)	A pair of stags
5.	Where did Llywelyn try to find his son? (l. 19)	In his cradle In his crot In his bed
6.	Which animal did Gelert find beside his son? (l. 25)	A wolf A hound Gelert

A.2.2. Session B

Tchang, a young boy from China, was on his way to visit the Great Wizard of the West. Tchang needed to ask the Wizard why he and his mother were so poor. On his journey, he came across a huge dragon. It was so frightening Tchang was about to run away. But the dragon called to him:

"Don't be frightened! I'm quite harmless. Tell me why you want to cross my river."

Tchang explained that he needed to ask the Great Wizard of the West an important question.

When Pearl the Dragon heard the question, it smiled.

"You are a good lad, Tchang", it said. "The Great Wizard will certainly be able to tell you. He knows everything. Hop on my back and I'll have you across in a jiffy".

On the far side of the river, Tchang thanked the dragon.

"Think nothing of it!" the dragon replied cheerfully. "That's why I'm here for. Oh, by the way. While you are there, could you please ask the Wizard why I can't fly?" Every dragon in China can fly, except me."

Naturally, Tchang said yes. He set off again towards the West with two questions going around and around his head. Forty-nine days later, he came to the golden palace of the Great Wizard of the West. The palace was carved out of a mountain. It took Tchang a whole day to climb the million steps up to the huge door. A brilliant and massive coin was painted on it. When he pulled on the bell rope, the mountain suddenly shook. Flocks of eagles rose squawking into the air from a thousand golden towers.

The great doors of the palace swung open. Tchang found himself in a mighty hall. It was so high he couldn't see the ceiling for clouds. On a throne at the end of the hall sat the Great Wizard. He glared down at Tchang.

"Well?" he bellowed. "What do you want, boy?"

Tchang tried to stop shaking. "I... I have two questions to ask you, sir!"

"HAH!" shouted the Wizard. "Then you may as well go home right now! I will only answer ONE question. If you ask me two, I won't answer any of them. So there!"

Tchang was so scared and disappointed he thought his legs would fold underneath him. He focused his attention on the painting of a soldier. He remembered all the obstacles on the way. What could he do? There was his poor mother's question, then the dragon's question. He desperately wanted to know the answer to the first question, but he also knew he couldn't

let his friend down. So he answered sadly: “Then I will ask you one question. Why can’t the dragon fly?”

Question	Answer
1. What did Tchang initially want to ask the Wizard? (l. 2)	Why he is so poor Why he and his mother are so poor Why his family is so poor
2. What is the name of the dragon? (l. 6)	Pearl
3. What did the dragon want to ask the Wizard? (l. 10)	Why he can’t fly
4. How many days did Tchang travel from the river to the Palace? (l. 15)	49
5. In which room did Tchang meet the Wizard? (l. 18)	In a hall
6. What did the painting remind Tchang of? (l. 26)	Of the obstacles on the way Of the obstacles he had to go through

A.3. Reading comprehension

“In this activity, you are going to read two texts. For each text, you will be asked one question, and you will have 3 minutes 45 seconds to answer. You can provide your answer using the keyboard. Spelling is not taken into account, as long as I can understand what you mean!”

A.3.1. Session A**Text 1**

He struck a match. There was a candle on the table and he lighted it. The children saw a large bare kitchen with a stone floor. There were no curtains. The chairs were in one corner and the pots, pans, brooms and crockery in another. There was no fire, and the black grate showed cold, dead ashes.

In the dining room there was a muddled maze of dusty furniture. There was a table certainly, and chairs, but there was no supper.

In each room was the same kind of blundering half arrangement of furniture, but there was nothing to eat; even in the cupboard there were only a rusty cake-tin and a broken plate.

Question

What does the text tell us about the last occupants of the house?

Explain fully, giving evidence from the text.

Scoring system

Answers are given a score of 0, 1, 2 or 3 based on the following criterion.

0 point. Incorrect answer: no reference to the occupants' behaviour (*e.g.* : "there was only a rusty cake-tin").

1 point. Correct answer without precise justification from the text (*e.g.* : "they were in a hurry"; "they left a long time ago"; "they were poor", "they were neglectful"). The answer is also counted as correct if it does not mention the occupants but indirectly refers to their

behaviour (it was messy).

2 points. Correct answer and one justification from the text (*e.g* : “they left a long time ago because it was dusty”)

3 points. Correct answer and more than one justification from the text (*e.g* : “they might not of been very wealthy and they must of been a bit careless because there was dead ashes on the floor, and also there was an old ,rusty tin cake holder with a broken plate”)

Text 2

The tractor was ploughing faster. Father was falling further behind all the time. There was nothing he could do about it. But he kept going and talking to the horses as he ploughed, sweetening them on like he always did. The crowd were on Father’s side. Everyone loves a loser I thought and there was tears coming in my eyes. They were all clapping and cheering him every time he turned.

So was I. But it didn’t do Father nor the horses much good. I wanted to run off. I did not ever want to look but I had to. I was there at the end of the furrow each time Father came back and he would give us a smile and I would try to give as good a one back. That weren’t at all easy I can tell you.

Question

What can you conclude from the text about how the narrator was feeling while his father was trying to plough as fast as the tractor?

Explain fully, giving evidence from the text.

Scoring system

Answers are given a score of 0, 1, 2 or 3 based on the following criterion.

0 point. Incorrect answer: does not relate to the narrator's feeling, or infers non nuanced positive feelings (*e.g* : "he was happy"; "it was very fast")

1 point. Correct answer without precise justification from the text (*e.g* : "he was sad, upset")

2 points. Correct answer and one justification from the text (*e.g* : "he was upset, he did not want to watch")

3 points. Correct answer and more than one justification from the text (*e.g* : "I think that the narrator felt sad because in the text it said that he or she wanted to look away and wanted to run away")

A.3.2. Session B**Text 1**

There were a lot of people in Manaus who lived like princes. But not the Carters. Because to get the juice from the rubber trees you need Indians who know the forest and understand the trees. And what we know for sure is that Indians are proud people who have their own lives. If you treat them like slaves they don't revolt or go on strike; they simply melt back into the forest, join their tribes and disappear.

That is what had happened to the Indians which the Carters had employed. Every month Mr Carter had lost some of his work force, and far from making his fortune, he was getting poorer and poorer.

Question

What can you conclude from the text about Mr Carter's attitude towards the Indians?

Explain fully, giving evidence from the text.

Scoring system

Answers are given a score of 0, 1, 2 or 3 based on the following criterion.

0 point. Incorrect answer: indicate positive attitudes, quote the text or describe the event without inferring the Carters' attitude toward the Indians (*e.g.* : "Mr carter likes the indians and he doesn't want to treat them like slaves"; "Every month mr carter had lost some of his work force and far from making his fortune ,he was poorer and poorer")

1 point. Correct answer without precise justification from the text: indicate negative attitudes toward the Indians. Negative adjectives alone are accepted. (*e.g.* : "he is not nice to the Indians")

2 points. Correct answer and one justification from the text (*e.g.* : "I don't think Mr Carter is nice to Indians because he was losing the Indians that probably worked for him")

3 points. Correct answer and more than one justification from the text. (*e.g.* : "He was not treating them well because it says that they are proud, and if you treat them like slaves they disappear").

Text 2

I went to St Matthias Primary on the Warwick Road in London. It was one of those old brick schools which look a bit like a prison or a hospital, with windows so high you could not see out of them but just catch glimpses of blue sky. I wasn't a very dazzling pupil and often made mistakes, which meant standing in the corner or being thwacked across the knuckles with a

ruler.

The corner did not make a huge difference compared to the light I could barely see through the window. Books and stories became rather terrifying things, as the teacher was only interested in correct spelling and neat handwriting without any blotches. There was one good thing about school though, my first love, the brainy Belinda who I shared a desk with and whose work I tried to copy.

Question

How would you describe the writer's memories of school?

Explain fully, giving evidence from the text.

Scoring system

Answers are given a score of 0, 1, 2 or 3 based on the following criterion.

0 point. Incorrect answer: non nuanced positive feelings (*e.g.* : "i think the writers memories of school are good because they can remember allot of things like about it)

1 point. Correct answer without precise justification from the text: indicate negative memories, or a good memory because of Belinda (*e.g.* : "he did not like school")

2 points. Correct answer and one justification from the text (*e.g.* : "I think that the writer didn't like school a lot because in the text it said he was scared of making mistakes")

3 points. Correct answer: negative memories, or a good memory because of Belinda) and more than one justification from the text (*e.g.* : "He didn't like it, he wasn't very good and often got thwacked by a ruler and stood in a corner")

Appendix B

Counterbalancing of the idea generation tasks in Experiment 2

1.	AUT Pencil	AUT Bottle	JS Clouds	JS Fog
	Silence	Noise	Silence	Noise
2.	AUT Bottle	AUT Pencil	JS Fog	JS Clouds
	Noise	Silence	Noise	Silence
3.	AUT Bottle	AUT Pencil	JS Fog	JS Clouds
	Silence	Noise	Silence	Noise
4.	AUT Pencil	AUT Bottle	JS Clouds	JS Fog
	Noise	Silence	Noise	Silence
5.	JS Clouds	JS Fog	AUT Pencil	AUT Bottle
	Silence	Noise	Silence	Noise
6.	JS Fog	JS Clouds	AUT Bottle	AUT Pencil
	Noise	Silence	Noise	Silence
7.	JS Fog	JS Clouds	AUT Bottle	AUT Pencil
	Silence	Noise	Silence	Noise
8.	JS Clouds	JS Fog	AUT Pencil	AUT Bottle
	Noise	Silence	Noise	Silence

AUT = Alternative Uses Task; JS = Just Suppose

Appendix C

Instructions for the Alternative Uses Task in Experiment 2

C.1. Instructions for the item “pencil”

Everyone knows that you can use a pencil for drawing or writing, but a pencil could also have lots and lots of other interesting and unusual uses. We want you to think of some. Don't just think about uses you might have seen or heard before, use your imagination to try to come up with new ideas.

The great thing is there are no right or wrong answers. Try to come up with as many unusual ideas as you can.

If you say your answers out loud, I will write them down for you. OK? Let's go!

C.2. Instructions for the item “bottle”

Everyone knows that you can use a plastic bottle for drinking from, but a plastic bottle could also have lots and lots of other interesting and unusual uses. We want you to think of some. Don't just think about uses you might have seen or heard before, use your imagination to try to come up with new ideas.

The great thing is there are no right or wrong answers. Try to come up with as many unusual ideas as you can.

If you say your answers out loud, I will write them down for you. OK? Let's go!

Appendix D

School survey used in Experiment 3 (taking place in Corsica, France)

D.1. Version A

Tu vas voir plusieurs questions sur toi-même et ton environnement. Le but est de connaître ton avis. **Il n'y a pas de bonne ou de mauvaise réponse.** Essaie de choisir la réponse qui te semble la plus naturelle, en fonction de ce que tu as ressenti pendant ces **deux dernières semaines**. Si tu ne sais vraiment pas quoi répondre, tu peux laisser la ligne blanche et passer à la question suivante.

Penses-tu que la classe est bruyante ?

- ☐ Pas du tout bruyante ☐ Un peu bruyante ☐ Plutôt bruyante ☐ Très bruyante

Penses-tu que le niveau de bruit en classe est...

- ☐ Très faible ☐ Plutôt faible ☐ Plutôt fort ☐ Très fort

Sur une échelle de 0 à 10, à combien estimerais-tu le niveau de bruit en classe ?

Est-ce que tu es gêné(e) par le bruit en classe ?

- ☐ Pas du tout gêné(e) ☐ Un peu gêné(e) ☐ Plutôt gêné(e) ☐ Beaucoup gêné(e)

Généralement, face au bruit, tu es ...

- ☐ Pas du tout sensible ☐ Un peu sensible ☐ Plutôt sensible ☐ Très sensible

Généralement, dans la classe, tu te trouves ...

- ☐ Pas du tout bruyant(e) ☐ Un peu bruyant(e) ☐ Plutôt bruyant(e) ☐ Très bruyant(e)

Généralement, dans la classe, tu trouves tes camarades ...

- ☐ Pas du tout bruyants ☐ Un peu bruyants ☐ Plutôt bruyants ☐ Très bruyants

Indique si ces phrases sont vraies pour toi. Par exemple, si tu lis : “Tu adores cuisiner ”, mais que tu n’aimes pas du tout cuisiner, tu peux répondre “pas vrai du tout”.

Au cinéma, les chuchotements et bruits de nourriture te gênent.

- ☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

Chez toi, cela te gêne si les autres sont bruyants.

- ☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

Parfois, le bruit t’agace et te met sur les nerfs.

- ☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

Une musique que tu aimes peut te déranger si tu essayes de te concentrer.

- ☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

Souvent, tu as envie qu’il y ait un silence complet.

- ☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

Tu as du mal à te détendre dans un endroit bruyant.

- ☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

Tu te mets en colère si des gens bruyants t’empêchent de dormir ou de travailler.

- ☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

Tu as du mal à passer d’une chose à l’autre rapidement

- ☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

Cela te prend du temps de t'impliquer dans une nouvelle tâche

- ☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

C'est difficile pour toi de jongler entre deux choses à faire

- ☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

Après avoir été interrompu, tu as du mal à te reconcentrer sur ce que tu faisais

- ☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

Indique si ces situations t'arrivent souvent.

Tu as des difficultés à garder ta concentration si tu fais un travail simple.

- ☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Quand tu lis, tu te rends compte que tu n'es pas en train de penser au texte, et tu dois le lire à nouveau.

- ☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Tu fais des choses sans vraiment leur prêter attention

- ☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Tu te rends compte que tu écoutes d'une oreille, en pensant à quelque chose d'autre en même temps.

- ☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Pendant les leçons, tu penses à des choses qui n'ont pas de rapport.

- ☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Maintenant, est-ce que tu te sens calme ?

- ☐ Pas du tout calme ☐ Un peu calme ☐ Plutôt calme ☐ Très calme

Maintenant, est-ce que tu te sens détendu(e) ?

- ☐ Pas du tout détendu(e) ☐ Un peu détendu(e) ☐ Plutôt détendu(e) ☐ Très détendu(e)

Maintenant, est-ce que tu te sens agacé(e) ?

- ☐ Pas du tout agacé(e) ☐ Un peu agacé(e) ☐ Plutôt agacé(e) ☐ Très agacé(e)

Quand l'enseignant, ou un élève prend la parole pour s'adresser à la classe.

Tu as des difficultés à entendre ce que la personne dit

- ☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Tu es gêné(e) par le bruit qui se produit autour, dans la classe

- ☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Ton attention a tendance à être attirée par du bruit en classe

- ☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Si du bruit attire ton attention, tu as tendance à perdre le fil de la discussion

- ☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Quand l'enseignant, ou un camarade s'approche de toi pour te parler.

Tu as des difficultés à entendre ce que la personne te dit

- ☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Tu es gêné(e) par le bruit qui se produit autour, dans la classe

- ☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Ton attention a tendance à être attirée par du bruit en classe

- ☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Si du bruit attire ton attention, tu as tendance à perdre le fil de la discussion

☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Quand tu fais un exercice tout seul en classe.

Tu es gêné(e) par le bruit qui se produit autour, dans la classe

☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Ton attention a tendance à être attirée par du bruit en classe

☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Si du bruit attire ton attention, tu as tendance à perdre le fil de ta pensée

☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Quand tu fais un exercice en groupe, en classe.

Tu es gêné(e) par le bruit qui se produit autour, dans la classe

☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Ton attention a tendance à être attirée par du bruit venant de l'extérieur du groupe

☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Si du bruit attire ton attention à l'extérieur du groupe, tu as tendance à perdre le fil de la discussion

☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

D.2. Version B

Tu vas voir plusieurs questions sur toi-même et ton environnement. Le but est de connaître ton avis. **Il n'y a pas de bonne ou de mauvaise réponse.** Essaie de choisir la réponse qui te semble la plus naturelle, en fonction de ce que tu as ressenti pendant ces **deux dernières semaines**. Si tu ne sais vraiment pas quoi répondre, tu peux laisser la ligne blanche et passer à la question suivante.

Quand l'enseignant, ou un élève prend la parole pour s'adresser à la classe.

Tu as des difficultés à entendre ce que la personne dit

☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Tu es gêné(e) par le bruit qui se produit autour, dans la classe

☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Ton attention a tendance à être attirée par du bruit en classe

☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Si du bruit attire ton attention, tu as tendance à perdre le fil de la discussion

☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Quand l'enseignant, ou un camarade s'approche de toi pour te parler.

Tu as des difficultés à entendre ce que la personne te dit

☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Tu es gêné(e) par le bruit qui se produit autour, dans la classe

☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Ton attention a tendance à être attirée par du bruit en classe

☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Si du bruit attire ton attention, tu as tendance à perdre le fil de la discussion

☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Quand tu fais un exercice tout seul en classe.

Tu es gêné(e) par le bruit qui se produit autour, dans la classe

☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Ton attention a tendance à être attirée par du bruit en classe

☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Si du bruit attire ton attention, tu as tendance à perdre le fil de ta pensée

☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Quand tu fais un exercice en groupe, en classe.

Tu es gêné(e) par le bruit qui se produit autour, dans la classe

☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Ton attention a tendance à être attirée par du bruit venant de l'extérieur du groupe

☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Si du bruit attire ton attention à l'extérieur du groupe, tu as tendance à perdre le fil de la discussion

☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Maintenant, est-ce que tu te sens calme ?

- ☐ Pas du tout calme ☐ Un peu calme ☐ Plutôt calme ☐ Très calme

Maintenant, est-ce que tu te sens détendu(e) ?

- ☐ Pas du tout détendu(e) ☐ Un peu détendu(e) ☐ Plutôt détendu(e) ☐ Très détendu(e)

Maintenant, est-ce que tu te sens agacé(e) ?

- ☐ Pas du tout agacé(e) ☐ Un peu agacé(e) ☐ Plutôt agacé(e) ☐ Très agacé(e)

Indique si ces situations t'arrivent souvent.

Tu as des difficultés à garder ta concentration si tu fais un travail simple.

- ☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Quand tu lis, tu te rends compte que tu n'es pas en train de penser au texte, et tu dois le lire à nouveau.

- ☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Tu fais des choses sans vraiment leur prêter attention

- ☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Tu te rends compte que tu écoutes d'une oreille, en pensant à quelque chose d'autre en même temps.

- ☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Pendant les leçons, tu penses à des choses qui n'ont pas de rapport.

- ☐ Presque jamais ☐ Peu souvent ☐ Assez souvent ☐ Très souvent

Indique si ces phrases sont vraies pour toi. Par exemple, si tu lis : “Tu adores cuisiner ”, mais que tu n’aimes pas du tout cuisiner, tu peux répondre “pas vrai du tout”.

Tu as du mal à passer d’une chose à l’autre rapidement

☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

Cela te prend du temps de t’impliquer dans une nouvelle tâche

☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

C’est difficile pour toi de jongler entre deux choses à faire

☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

Après avoir été interrompu, tu as du mal à te reconcentrer sur ce que tu faisais

☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

Au cinéma, les chuchotements et bruits de nourriture te gênent.

☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

Chez toi, cela te gêne si les autres sont bruyants.

☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

Parfois, le bruit t’agace et te met sur les nerfs.

☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

Une musique que tu aimes peut te déranger si tu essayes de te concentrer.

☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

Souvent, tu as envie qu’il y ait un silence complet.

☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

Tu as du mal à te détendre dans un endroit bruyant.

- ☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

Tu te mets en colère si des gens bruyants t'empêchent de dormir ou de travailler.

- ☐ Pas vrai du tout ☐ Un peu vrai ☐ Plutôt vrai ☐ Tout à fait vrai

Penses-tu que la classe est bruyante ?

- ☐ Pas du tout bruyante ☐ Un peu bruyante ☐ Plutôt bruyante ☐ Très bruyante

Penses-tu que le niveau de bruit en classe est...

- ☐ Très faible ☐ Plutôt faible ☐ Plutôt fort ☐ Très fort

Sur une échelle de 0 à 10, à combien estimerais-tu le niveau de bruit en classe ?

Est-ce que tu es gêné(e) par le bruit en classe ?

- ☐ Pas du tout gêné(e) ☐ Un peu gêné(e) ☐ Plutôt gêné(e) ☐ Beaucoup gêné(e)

Généralement, face au bruit, tu es ...

- ☐ Pas du tout sensible ☐ Un peu sensible ☐ Plutôt sensible ☐ Très sensible

Généralement, dans la classe, tu te trouves ...

- ☐ Pas du tout bruyant(e) ☐ Un peu bruyant(e) ☐ Plutôt bruyant(e) ☐ Très bruyant(e)

Généralement, dans la classe, tu trouves tes camarades ...

- ☐ Pas du tout bruyants ☐ Un peu bruyants ☐ Plutôt bruyants ☐ Très bruyants

Appendix E

Letter Cancellation Task used in Experiment 3 (taking place in Corsica, France)

[Instructions translated from French]. In this game, you will see scrambled letters. Your goal is to cross all the “T” and “G”. Start with the top of the page and scan the paper sheet as fast as you can, from left to right, crossing all the “T” and “G”. Once you passed a line, you cannot go back! Are you ready?

U	B	Z	M	T	X	J	A	I	C	W	B	S	P	O	B
E	N	H	U	D	L	F	K	E	Q	R	F	N	X	T	K
C	V	O	S	R	Z	B	J	Y	T	D	H	I	M	C	A
F	I	Y	G	J	M	Z	P	U	L	S	K	O	Y	E	L
D	L	N	K	I	E	W	C	R	B	J	A	Q	V	W	N
E	R	C	T	D	X	G	Z	O	D	T	N	L	B	P	O
V	F	W	Q	S	L	V	F	U	G	V	C	R	K	I	R
B	H	O	M	Y	A	E	N	P	H	S	E	W	G	Q	S
I	A	K	X	S	Q	L	A	Y	D	J	N	B	H	M	U
C	V	J	U	T	G	X	M	F	H	S	A	Z	O	T	Y
W	D	N	B	P	I	Z	K	C	G	U	X	F	Y	D	F
F	M	G	Z	R	O	N	V	J	E	P	I	U	P	N	J
A	K	P	X	U	E	T	D	Y	O	L	Z	M	H	S	X
I	W	C	Z	L	G	X	R	U	S	J	F	B	Q	P	V
F	N	O	R	I	W	C	Q	L	M	D	C	G	K	Y	H
J	X	P	U	K	M	V	D	E	A	V	Q	J	T	W	M
V	S	E	G	T	Y	B	H	R	L	Z	D	C	X	F	G
I	R	H	O	W	A	S	V	J	N	Q	B	E	U	P	I
Q	Y	M	C	P	X	I	O	A	E	G	T	U	A	Y	T
F	V	B	K	L	Q	R	D	M	Y	H	J	G	X	H	W
W	L	A	Z	S	W	H	N	K	Q	Z	O	K	R	T	Z

Appendix F

Content of the mindfulness short-term intervention in Experiment 3

The content of each session is briefly described in chronological order. The activities labelled with an * are available on the website <http://kidyoga.fr/yoga-tutorials.html>

Session 1

- [Meditation] Body scan: being aware of the different parts of the body, and of their contact with the physical environment
- [Body posture] Lengthening the back and the spine
- [Breathing] Deep breathing while being aware of the movements of the rib cage
- [Meditation] The hut: imagining a hut, with its physical characteristics (materials, decoration, smells, sounds) and the emotion they trigger
- [Breathing] The triangle*: working on the length of expiration / inspiration using three sides of a triangle as a visual help
- [Visual attention] The circle and the dot*: focusing the attention on a point in space
- [Breathing] The bee: humming while expiring
- [Body posture] Lengthening the back and the spine
- [Meditation] Body scan

Session 2

- [Meditation] Body scan
- [Auditory attention] Being aware of the sounds in the room, and outside of the room
- [Breathing and Body posture] Breathing deeply while lengthening and twisting the back

- [Body posture] Lengthening the back and the spine
- [Meditation] The tree: imagining and contemplating a tree
- [Breathing and Body posture] Inspiring and expiring while performing arm movements
- [Auditory attention] Being aware of the sounds in the room, and outside of the room
- [Meditation] Body scan

Session 3

- [Meditation] Body scan
- [Body posture] Lengthening the back and the spine
- [Breathing and Body posture] Breathing deeply while lengthening and twisting the back
- [Meditation] The hut
- [Breathing] The stairs*: Working on the length of expiration / inspiration using the shape of stairs as a visual help
- [Body posture] The eagle: crossing the legs and arms while keeping one's balance
- [Body posture] Ten fingers*: awareness of hands and fingers movements
- [Meditation] Presence

Session 4

- [Meditation] Body scan
- [Body posture] Stretching each body part, and massaging the face
- [Breathing and Body posture] Inspiring and expiring while performing arm movements
- [Body posture] The tree: standing on one foot while keeping one's balance
- [Meditation] The tree: imagining and contemplating a tree
- [Sensory Awareness] Being aware of one's body, and of the sounds in the environment

- [Breathing and Body posture] Inspiring and expiring while contracting / relaxing the body
- [Breathing] The bee: humming while expiring
- [Meditation] The hut

Appendix G

List of activities included in the long-term sound awareness intervention in

Experiment 3

1. Everyone gets up
2. Everyone gets up while lifting the chair carefully
3. Everyone takes a book from their drawer
4. Everyone actions their BIC
5. Everyone turns the pages of their notebook
6. Everyone searches for a pen in their pencil case
7. Everyone whispers
8. Three people talk out loud
9. Everyone talks out loud
10. Everyone sings